

The Honorable Cory Gardner  
354 Russell Senate Office Building  
Washington, D.C. 20510

The Honorable Gary Peters  
724 Hart Senate Office Building  
Washington, D.C. 20510

30 October 2015

Dear Senators Gardner and Peters:

On behalf of the American Geophysical Union (AGU) and its more than 60,000 Earth and space scientists, I want to thank the Senate America COMPETES working group for giving stakeholders the opportunity to weigh in on this important bill. The purpose of AGU is to promote discovery in Earth and space science for the benefit of humanity, and we look forward to continuing to work with you in strengthening the American scientific enterprise.

The America COMPETES Act was written and designed to be aspirational - the blueprint for how America can continue to be the world's leader in innovation and scientific achievement. Strong federal support and investment in STEM (science, technology, engineering, and mathematics) education is critical if our nation is going to remain a leader in innovation.

The geosciences are a vital part of our scientific enterprise. Geoscience research covers many aspects of our daily lives, from the discovery of critical minerals vital to modern technology, to accurate daily weather forecasting, to the discovery of new energy sources, to understanding how space weather will impact telecommunications. As such, continued investment and innovation in the geosciences enables the U.S. to safely build sustainable infrastructure, improve resilience to natural hazards, and harness energy sources more efficiently to fuel continued industrial and economic growth.

#### DISCUSSION THEMES

- 1. How does the availability of STEM graduates affect corporate decision-making about where to conduct research and manufacture goods?**

#### ADDRESSING THE WORKFORCE SHORTAGE

There is an emerging workforce shortage of geoscientists, which within the next decade could lead corporations to look outside the United States for geoscientists. In the decade between 2012 and 2022, about 48% of the geoscience workforce will retire, creating a shortage of 150,000 geoscientists.<sup>1</sup> Overall, several reports suggest that the American workforce will need to create one million more STEM professionals than the U.S. will produce at current rates.<sup>2</sup> Federal funding and support underlies the pipeline of geoscientists in America; without a strong geoscience

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<sup>1</sup> Wilson, Carolyn E. Introduction. *Status of the Geoscience Workforce 2014*. Alexandria, VA: American Geological Institute, 2014. li. Print.

<sup>2</sup> *REPORT TO THE PRESIDENT ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS*. Rep. President's Council of Advisors on Science and Technology, Page 1, Feb. 2012. Web. 20 Oct. 2015.

workforce, corporations will not be able to depend solely on American scientists to fill their geoscience research needs and positions.

Federal support enables early career scientists to pursue graduate education by providing funding for graduate research. In addition, federal research enables scientists to get the undergraduate and graduate research experiences necessary for a career in industry. NSF alone supports twenty percent of federally funded research done at universities,<sup>3</sup> and NSF's Research Experiences for Undergraduates (REU) funds research experiences for undergraduate students in areas of NSF funded-science, including the geosciences. NSF is currently funding 626 REU sites.<sup>4</sup> Sites generally consist of 10 students, and give students the opportunity to work on a research project in close coordination with faculty and researchers. In the summer of 2013, the NSF Geosciences Directorate (GEO) supported 728 REU site positions. As positive as this level of support is, however, there were 8,415 applications for these positions; NSF was only able to accept and fund 8.65% of undergraduates who applied.<sup>5</sup> This is especially troubling since research shows that early engagement of students in field research has a positive impact on student retention in STEM education.<sup>6</sup> The federal government should continue to support programs that enable undergraduate students to get the field experience needed to pursue a career in industry.

Given the enormity of the workforce shortage, we cannot afford to leave talent untapped. As such, underrepresented minority groups will be critical to meeting our workforce needs. Overall, the federal government will need strong investments in a stronger K-12 STEM education foundation, increased participation by underrepresented groups, and more STEM education programs at two-year colleges. NSF has made extensive investments in STEM education at two year colleges through the Advanced Technology Education (ATE) program<sup>7</sup> as well as through its IUSE/TUES/CCLI programming, aimed at improving STEM curriculum, education materials, and teaching methods.<sup>8</sup> Programs like NSF GEOPATHS<sup>9</sup> are helping institutions create programming that supports underrepresented minorities in completing STEM degrees.

## **2. To maximize the use of limited resources, how can the Federal Government, in coordination with the private sector and academia, best prioritize STEM education investments and help respond to shifting academic and private sector workforce needs?**

### SCALE UP PROVEN PROGRAMS

The federal government should scale up programs that have been created to foster strong science curricula at the undergraduate level so that they can be applied across entire institutions and

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<sup>3</sup> Killgrove, Kristina. "These Students Spent Their Summer Vacation Unearthing An Ancient American Empire." *Forbes*. Forbes Magazine, <http://www.forbes.com/sites/kristinakilgrove/2015/10/15/these-students-spent-their-summer-vacation-unearting-an-ancient-american-empire/>, 15 Oct. 2015. Web. 20 Oct. 2015.

<sup>4</sup> "Research Areas." *Search Results for REU Sites*. National Science Foundation, [https://www.nsf.gov/crssprgm/reu/list\\_result.jsp](https://www.nsf.gov/crssprgm/reu/list_result.jsp), n.d. Web. 30 Oct. 2015.

<sup>5</sup> Patino, Lina (Program Director, NSF Division of Earth Sciences). "GEO REU Sites." 2 July 2015. E-mail.

<sup>6</sup> See Id. 2.

<sup>7</sup> Carter, V. Celeste, and David B. Campbell. "Research Areas." *Advanced Technological Education*. National Science Foundation, [http://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=5464](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5464), n.d. Web. 30 Oct. 2015.

<sup>8</sup> IUSE is NSF's Institutional Undergraduate Science Education program which works to better understand how students best learn STEM topics. TUES is the Transforming Undergraduate Education and Science program. CCLI is the Course Curriculum Laboratory Improvement program.

<sup>9</sup> Karsten, Jill. "Research Areas." *Improving Undergraduate STEM Education: Pathways into Geoscience*. National Science Foundation, [http://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=505169](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505169), n.d. Web. 30 Oct. 2015.

regions, to increase the impact of these programs. The federal government should also prioritize programs that encourage increased diversity within the STEM fields at all levels. Public-private partnerships should be encouraged to scale-up and sustain existing programs in all of these areas. In addition to supporting programs that have been proven to work, the federal government should allow some flexibility in federal funding, to provide a balance between research and innovation on the one hand and broad implementation on the other, with a particular emphasis on support for activities that make it easier for institutions nationwide to adapt and bring into use new ideas coming from the research.

Examples of past successful programs that should be emulated include NSF's Course Curriculum Laboratory Improvement (CCLI) program, which led to NSF's Transforming Undergraduate Education and Science (TUES) program. The 2014 consolidation of federal STEM education programs, eliminated the TUES program.<sup>10</sup> These programs were consolidated into the Institutional Undergraduate Science Education (IUSE) program.<sup>11</sup> The IUSE program invests in evidence based and evidence-generating approaches to understanding STEM learning. The goals of the program are to increase the number and diversity of STEM students, ensure students are prepared to enter STEM fields, and improve STEM education outcomes.

Outcomes from these programs include:

- The On the Cutting Edge Professional Development program for geoscience faculty which has involved more than 1800 geoscience faculty and 600 postdoctoral fellows and graduate students to improve their teaching. The program has created online teaching resources for faculty visited by a million users each year, resulting in improved instruction nationwide.<sup>12</sup>
- The SAGE-2YC program engages geoscience faculty at two-year colleges in a learning community, coaching them on best practices for teaching while building connections between two-year and four-year institutions. This effort has fostered interactions that improve the quality of geoscience education at two-year colleges.<sup>13</sup>
- The Minorities Striving and Pursuing Higher Degrees of Success in Earth System Science (MS PHD's) Professional Development Program is a year-long program that serves about 100 minority students a year. The MS PHD's program supports students by connecting them with mentors, enabling them to attend scientific conferences and developing the scientific and professional skills they need to pursue meaningful careers in the Earth sciences.<sup>14</sup>
- InTeGrate is a \$10 million, five year (2012-2016) NSF STEP (STEM Talent Expansion Program) Center, funded by NSF's Directorates for the Geosciences (GEO) and Education & Human Resources (EHR). InTeGrate seeks to implement teaching about the Earth in the

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<sup>10</sup> "NSF TUES Is Cancelled: Where Will CS Ed Funding Come From?" Web log post. *Computing Education Blog*, <https://computinged.wordpress.com/2013/04/24/nsf-tues-is-cancelled/>, N.p., 24 Apr. 2013. Web. 30 Oct. 2015.

<sup>11</sup> "Improving Undergraduate STEM Education (IUSE: EHR)." *Improving Undergraduate STEM Education (IUSE: EHR) (nsf14588)*. National Science Foundation, <http://www.nsf.gov/pubs/2014/nsf14588/nsf14588.htm>, n.d. Web. 30 Oct. 2015.

<sup>12</sup> C. A. Manduca et al., SPOR: Science Prize for Online Resources in Education: On the Cutting Edge: Teaching Help For Geoscience Faculty. *Science* 327, 1095 (2010).

<sup>13</sup> "Supporting and Advancing Geoscience Education in Two-Year Colleges." *SAGE 2YC*. Science Education Research Center at Carleton College, <http://serc.carleton.edu/sage2yc/index.html>, n.d. Web. 30 Oct. 2015.

<sup>14</sup> Karsten, Jill. "Research Areas." *NSF Award Search: Award#0503536*. National Science Foundation, [http://www.nsf.gov/awardsearch/showAward?AWD\\_ID=0503536&HistoricalAwards=false](http://www.nsf.gov/awardsearch/showAward?AWD_ID=0503536&HistoricalAwards=false), 1 Aug. 2005. Web. 30 Oct. 2015.

context of societal issues across the undergraduate curriculum and create geoscientists who can work on interdisciplinary teams to solve society's biggest issues. Now in its fourth year, InTeGrate has pursued this transformative goal by engaging teams of faculty in developing new teaching materials, testing these materials in diverse instructional settings, and supporting institutions implementing model programs that make use of these new materials. InTeGrate has created a national community of over 1000 faculty and administrators, thereby transforming the opportunities that students have to learn about the Earth.<sup>15</sup>

### **3. What factors should Federal agencies consider to measure the impact and success of the Federal STEM education portfolio and to decide whether to expand, modify, or replace individual programs, given limited resources?**

#### LESSONS LEARNED FROM THE 2014 EDUCATION CONSOLIDATION

The 2014 STEM education consolidation, aimed at streamlining and improving the efficacy of existing federal STEM education programs, had unintended consequences. The consolidation impacted the ability of different disciplines in STEM to meet specific education and workforce development challenges in that field. Geoscience faces specific challenges addressing field education and diversity that are not shared by, for example, physics. To the extent we use one size fits all solutions, we reduce the capacity of individual disciplines to meet the desired workforce goals.

Additionally, within disciplines, there are different needs for different fields. For example, to meet workforce needs, America's geoscience employers need students who are prepared to be both meteorologists and economic geologists. While these students may appear to be served by STEM or Geoscience programs, in reality they have different research and workforce preparation needs. Because each specialty focuses on its own individualized programming and recruiting, centralization of these opportunities reduces their impact.

The consolidation has also impacted graduate students' ability to attend meetings and present their research. Before further measures are taken, a system-wide evaluation of the impacts of this consolidation and other measures meant to improve federal STEM and fellow's programs needs to be undertaken. Using metric and assessment analyses will be incredibly important and helpful in a system-wide rethinking. The 2010 review of NOAA's education programs is a useful example of the type of review that should be undertaken.<sup>16</sup> We recommend using a third party to collect data, assess results, and develop good metrics for analyzing programs.

#### MATCHING INDUSTRY NEEDS WITH UNIVERSITY PROGRAMS

When evaluating the success of federal STEM education programs, agencies should take into account the skills industry needs compared with what skills students are learning in university. A good example of how this can be done is Dr. Sharon Mosher's geoscience undergraduate education summit with educators and employers. In 2014, Dr. Mosher at the University of Texas received

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<sup>15</sup> "About Integrate." *About This Project*. Science Education Research Center at Carleton College, <http://serc.carleton.edu/integrate/about/index.html>, 7 Aug. 2015. Web. 30 Oct. 2015.

<sup>16</sup> Feder, Michael A. "2." *NOAA's Education: Review and Critique*. Ed. John W. Farrington. Washington, D.C.: National Academies, 2010. 29-50. Print.

NSF funding to examine geoscience undergraduate education and the gap between the skills faculty perceive as important for students<sup>17</sup> and the skills industry perceives as important for students.<sup>18</sup> The first meeting brought together university professors, the second meeting brought together industry leaders, and the third upcoming meeting will gather department chairs, deans, and other administrative leaders to ask them to close the skills gap between undergraduate education and industry needs.

#### **4. How can Federal agencies best identify and encourage implementation of promising, research-driven STEM education teaching models and best practices?**

##### UTILIZING EXISTING RESEARCH

The federal government has already spent a tremendous amount of energy and federal dollars to understand how best to teach science to students and how students learn. Federal agencies should widely disseminate the findings of the research that has been done and provide funding to enable schools and teachers to put this research into place. To encourage early adoption and best practices, federal agencies should think about reward systems that will encourage schools to adopt these practices.

For example, research into students' motivation and attitudes at the Science Education Research Center (SERC) at Carleton College<sup>19</sup> is just one example of NSF funded research aimed at better understanding how students think, with the goal of ultimately improving student achievement. SERC also coordinates dissemination and learning across the Earth sciences and beyond. The goal of these programs is to incorporate the best information about how students think into the classroom so that student achievement will improve.

#### **5. What actions can the Federal Government, private sector, and academia pursue to broaden STEM participation and provide education and research opportunities to students from all backgrounds?**

##### STRENGTHENING K-12 GEOSCIENCE EDUCATION

One way to increase participation in STEM education is to improve K-12 STEM programs and broaden both the disciplines and activities that are included in those programs. For example, K-12 STEM programs should incorporate out-of-the-classroom events to provide hands-on learning. In addition, these programs should include classes in the geosciences. The Status of the Geoscience Workforce 2014 report found that approximately half of the geoscientists surveyed – at all degree levels – had taken a formal Earth science course while in high school, while fewer than 30% of high school graduates take a high school geoscience course (e.g., Earth science, oceanography, or meteorology). The report suggests that early exposure to an Earth science class

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<sup>17</sup> Mosher, Sharon, comp. [http://www.jsg.utexas.edu/events/files/Future\\_Undergrad\\_Geoscience\\_Summit\\_report.pdf](http://www.jsg.utexas.edu/events/files/Future_Undergrad_Geoscience_Summit_report.pdf). Rep. National Science Foundation, Jan. 2014. Web. 20 Oct. 2015.

<sup>18</sup> Mosher, Sharon, comp. "Geoscience Employers Workshop Outcomes." *EAR-1347209: The Future of Undergraduate Geoscience Education Geoscience Employers Workshop Outcomes*, National Science Foundation. [http://www.jsg.utexas.edu/events/files/Employers\\_Workshop\\_outcomes.pdf](http://www.jsg.utexas.edu/events/files/Employers_Workshop_outcomes.pdf), Web. 20 Oct. 2015.

<sup>19</sup> "Affective Domain." *Affective Domain*. Science Education Research Center at Carleton College, <http://serc.carleton.edu/NAGTWorkshops/affective/index.html>, 15 Sept. 2014. Web. 22 Oct. 2015.

may inspire a career-long interest in Earth science, and as such improving K-12 geoscience education promises to strengthen the geoscience workforce more broadly.

#### EXPANDING ON PROGRAMS THAT WORK

In 2001, recognizing that geosciences were some of the least diverse sciences, with only 7% of geoscientists being minorities,<sup>20</sup> NSF's Geosciences Directorate (GEO) initiated the Opportunities for Enhancing Diversity in the Geosciences (OEDG) program. The program officially ended in 2013. The federal government should support programs like NSF's OEDG, which was designed to increase minority participation in the geosciences and to increase society's awareness of the value of the geosciences. The program provided support for both short-term proof-of-concept programs and full-scale programs. Funding for full-scale programs was conditioned on programs' ability to sustain the program without additional funding. Grants were aimed at establishing or enhancing geoscience education and research opportunities at historically black colleges, Hispanic-serving institutions, minority-serving institutions, and tribal colleges and universities. The program funded about 14,000 students per year.<sup>21</sup> A National Research Council found that some of the successes of the program included: the creation of new degree programs at minority-serving institutions (MSI), new partnerships between MSI's and 4-year and research institutions, slight increases in number of undergraduate majors, and a better understanding how to recruit and retain minorities in Earth science.<sup>22</sup>

We support NSF's INCLUDES (Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science) program, which will build off of the successes of OEDG. NSF INCLUDES "aims to develop a scalable, national initiative to increase the preparation, participation, advancement, and potential contributors of those that have been traditionally underserved and/or underrepresented in the STEM enterprise."<sup>23</sup> NSF INCLUDES plans to support programs that engage underrepresented ethnic/racial groups, women and girls, and persons with disabilities. The program will provide grants to programs that are scalable, sustainable, and impactful as determined by performance indicators.<sup>24</sup>

#### MAKE EXISTING OPPORTUNITIES MORE ACCESSIBLE

Students need better access to all of the resources that can help them get into and succeed in undergraduate education (including scholarships, etc.) and, in turn, can help schools, faculty and employers recruit and retain students. AGU, in coordination with several partners, is working on an initiative that will include a virtual platform and a collaborative infrastructure to help engage, retain, and prepare two- and four-year-college undergraduate Earth, ocean, atmospheric, and

<sup>20</sup> "Opportunities for Enhancing Diversity in the Geosciences (OEDG)." *Program Solicitation*. National Science Foundation, <http://www.nsf.gov/pubs/2004/nsf04590/nsf04590.htm>, n.d. Web. 15 Oct. 2015.

<sup>21</sup> "Federal Earth Science Education and Training Programs." *Preparing the next Generation of Earth Scientists: An Examination of Federal Education and Training Programs*. Washington, D.C.: National Academies, 2013. 13-18. Print.

<sup>22</sup> "Appendix D: Program Evaluation Information Provided by the Agencies." *Preparing the next Generation of Earth Scientists: An Examination of Federal Education and Training Programs*. Washington, D.C.: National Academies, 2013. 67-78. Print.

<sup>23</sup> "Research Areas." *NSF FY16 Budget Request*. National Science Foundation, [http://www.nsf.gov/news/news\\_summ.jsp?cntn\\_id=134034](http://www.nsf.gov/news/news_summ.jsp?cntn_id=134034), 2 Feb. 2015. Web. 30 Oct. 2015.

<sup>24</sup> "INCLUSION ACROSS THE NATION OF COMMUNITIES OF LEARNERS THAT HAVE BEEN UNDERREPRESENTED FOR DIVERSITY IN ENGINEERING AND SCIENCE (NSF INCLUDES)." (n.d.): n. pag. *NSF Budget FY 2016*. National Science Foundation, 2015. [https://www.nsf.gov/about/budget/fy2016/pdf/44\\_fy2016.pdf](https://www.nsf.gov/about/budget/fy2016/pdf/44_fy2016.pdf), Web. 2 Oct. 2015.



space science students (including those who are considering becoming majors) for the workforce. The initiative will centralize programs and resources currently scattered across multiple professional societies, federal agencies, and others for students and then identify and try to fill gaps between existing resources and programs.<sup>25</sup>

The initiative has the capability of transforming education opportunities for geographically isolated students and helping students at schools with fewer resources access high quality programs. For instance, through the initiative's first offering, the Virtual Poster Showcase, students are currently able to participate and present their research without traveling to a meeting. Students can present their science, design a poster, review peers' posters and research, and have their posters and research judged by faculty-scientist judges. This is a great opportunity for student scientists, especially students unable to attend scientific conferences, to further their science, have their science reviewed, and learn from more senior scientists; all opportunities necessary for a scientist to advance in their field.

#### CITIZEN SCIENCE

As a community dedicated to advancing the understanding of Earth and space science, AGU has endorsed Senators Coons' and Daines' Crowdsourcing and Citizen Science Act of 2015 (S. 2113). We support the bill's intention to harness America's ingenuity and innovative talent by encouraging agencies to utilize citizen scientists. The Earth and planetary sciences and their applications have large implications for public health and safety, economic development, protection of our environment and ecosystems, and national security. Crowdsourcing and citizen science have the ability to accelerate America's advancement in these sciences and create numerous societal benefits. We also applaud the bills' intent to further the scope of scientific research and knowledge into nontraditional sectors and engage citizens in the sciences.

#### IMPORTANCE OF A SCIENCE LITERATE SOCIETY

The federal government should not undervalue the importance of all citizens receiving a quality STEM education even if they do not enter STEM fields. Citizens require a solid understanding of the Earth and space sciences to responsibly address many of the issues confronting society, such as climate variability, natural hazards, and resource availability. These problems will require complex interdisciplinary solutions. It is important to have a well-educated citizenry and workforce that can produce creative new solutions.

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<sup>25</sup> Furukawa, Harry, and Pranoti Asher, comps. "GeoLEAD." (n.d.): n. pag. *GeoLEAD*. American Geophysical Union, <http://dels.nas.edu/resources/static-assets/besr/miscellaneous/CER/2014/May/GeoLEAD%20infographic%20v14%20-%20gen%20audience.pdf>, May 2014. Web. 10 Oct. 2015.