"Unintentional Diplomats: International Science Engagement and Science Diplomacy by U.S. Higher Education Institutions"

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1. Introduction

Against a backdrop of global changes in the landscape of both higher education and science, as well as a worldwide increase in diplomatic efforts in science-related areas, AIEA leadership and science policy staff at the U.S. Department of State have been working together over the last two years to better understand international science, technology, engineering and mathematics (STEM) engagement by U.S. higher education institutions (HEI) and the potential implications of such engagement for U.S. science diplomacy. We report here on a survey that AIEA conducted on these topics in late 2012 and early 2013 and discuss the implications of its results.

Higher education is in a period of rapid, internationally stimulated change as it responds, for example, to the large unmet worldwide demand for higher education[1], increased impact of global university rankings[2], the development of Massive Open Online Courses (MOOCs) with the capacity for global dissemination[3], new patterns of international faculty[4] and student mobility[5], growing employer demand for globally competent graduates, and an increasingly global construction of knowledge across all disciplines and professions[6]. U.S. HEI are

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1 "Experts Assess Consequences of Global Surge in Demand for Higher Education." Chronicle for Higher Education. July 7, 2009. http://chronicle.com/article/Experts-Assess-Global-Surge-in/47357

2 "How Rankings are Reshaping Higher Education." 2013. Ellen Hazelkorn. http://arrow.dit.ie/cgi/viewcontent.cgi?article=1023&context=cserbk&sei-redir=1&referer=http%3A%2F%2Fscholar.google.com%2Fscholar%3Fstart%3D20%26q%3Dinternational%2Buniversity%2Brankings%26hl%3Den%26as_sdt%3D0%2C9#search=%22international%20university%20rankings%22 See also Ishikawa, M. (2009). University rankings, global models, and emerging hegemony. *Journal of Studies in International Education, 13,* 159–173

3 "MOOCs and Open Education: Implications for Higher Education." March 2013. Li Yuan and Stephen Powell. J CETIS: http://publications.cetis.ac.uk/2013/667

4 "Scientific mobility and international research networks: trends and policy tools for promoting research excellence and capacity building." Published online 05 April 2013. Merle Jacob and V. Lynn Meek. *Studies in Higher Education*.

5 International Institute of Education, Open Doors 2013, http://www.iie.org/Research-and-Publications/Open-Doors

6 For comprehensive discussions of these changes, see Altbach, P. G., Reisberg, L., & Rumbley, L. E. (2009). *Trends in global higher education: Tracking a revolution*. A report prepared for the UNESCO 2009 World Conference on Higher Education. Paris:

responding with renewed attention to campus-wide internationalization (ACE Mapping Internationalization[7], NAFSA Comprehensive Internationalization[8]).

As a result of such forces, STEM research and development has become increasingly globally collaborative, resulting in a heightened level of STEM internationalization in U.S. colleges and universities, as indicated by increasing rates of international co-authorship of science publications[9]), increased study abroad by students in STEM fields (Open Doors[10]), and the fact that a large proportion (41.8% in 2012-13) of the international students coming to the U.S. are in STEM fields. The individuals populating the STEM laboratories of U.S. colleges and universities are among the most internationally diverse groupings on campus, and STEM faculty are among the most internationally collaborative of the U.S. professoriate.

We know anecdotally about many individual HEI that have forged institutional STEM research partnerships with entities in other countries[11] and regions[12], that grant dual degrees in engineering with foreign universities[13], that partner with U.S. businesses on engineering education overseas[14], and that have opened international branch campuses with a STEM focus[15]. Statewide systems of higher education have also long partnered with other countries in science and agriculture[16], and consortia of U.S. HEI have partnered with countries[17] and have formed organizations to partner with regions[18] in STEM disciplines. A marked trend in internationalization on U.S. campuses has been the recent surge in global health programs[19].

Because there is no one place to find such information, it is difficult to understand the scope and trajectory of this phenomenon. In addition, little information has been collected from

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UNESCO. Retrieved from http://unesdoc.unesco.org/images/0018/001831/183168e.pdf and Knight, J. (2008). *Higher education in turmoil: The changing world of internationalization*. Rotterdam: Sense Publishers

[7] ACE Mapping Internationalization on U.S. Campuses, 2012, http://www.acenet.edu/news-room/Pages/2012-Mapping-Internationalization-on-U-S--Campuses.aspx

[8] NAFSA Comprehensive Internationalization: From Concept to Action, http://www.nafsa.org/Resource_Library_Assets/Publications_Library/Comprehensive_Internationalization__From_Concept_to_Action/

[9] National Science Foundation Science and Engineering Indicators, 2014, http://www.nsf.gov/statistics/seind14/

[10] International Institute of Education, Open Doors 2013, http://www.iie.org/Research-and-Publications/Open-Doors. STEM students are now a little over 1/5 of all study abroad students, a 24% growth over the last decade.

[11] For example, Colombia Purdue Advanced Research Institute; https://engineering.purdue.edu/CPIASR

[12] Pennsylvania State University's Alliance for Education, Science, Engineering and Development in Africa: http://aeseda.psu.edu/

[13] University of Rhode Island offers dual degrees with Germany and China; http://digitalcommons.uri.edu/cgi/viewcontent.cgi?article=1045&context=ojgee

[14] Arizona State University, USAID, Intel Corporation partner in Vietnam, in the Higher Engineering Education Alliance Program, HEEAP; http://heeap.org/

[15] For example, Georgia Tech's campuses in France and Singapore. http://www.global.gatech.edu/campuses/

[16] University of California system and Chile since 1963 http://chile.universityofcalifornia.edu/

[17] Portugal's partnership with MIT, Harvard medical school and Carnegie Mellon University: https://chronicle.com/article/Portuguese-Universities-Turn/124364/

[18] The Ibero American Science and Technology Education Consortium includes 5 US HEI and HEI from Spain and 12 countries in Latin America. http://www.istec.org/

[19] University Consortium for Global Health Meeting, 2008 http://www.cugh.org/sites/default/files/inaugural-meeting/inaugural-meeting-report.pdf

institutional leaders regarding the pace of internationalization in STEM fields, and STEM fields have been much more tangentially involved in institutional internationalization efforts than many other disciplines. The way that HEI in the U.S. are approaching the internationalization of their STEM disciplines, the degree to which STEM activities are part of overall internationalization planning, and the distinctive nature of STEM internationalization in contrast to other disciplines are not well understood.

It is this institutional level on which we have chosen to focus, for this is where strategic investments can occur, where institutions can act to bolster both individual and collective faculty and student efforts, and where HEI leaders can gain the larger perspective needed to best position their institutions in a new global context. It is also at this level that the structural, procedural, and policy challenges to STEM internationalization, both internal and external to HEI, might be identified, thus enabling a path to mitigating them. And it is at this level that the globally collaborative world of STEM research and other dimensions of HEI internationalization can be brought into alignment with each other. The global engagements that increasingly characterize STEM activities in U.S. HEI provide very solid foundations upon which long-standing bi-(and multi-)lateral relationships that foster international understanding, trust, and respect might be built.

Numerous studies from domestic (e.g., National Science Foundation[20] and the President's Council of Advisors on Science and Technology (PCAST)[21]) and international sources (*Nature* magazine[22], the UK Royal Society[23], and UNESCO[24]) have documented changes in what is now often referred to as the science, technology and innovation (STI)[25] global landscape. Many nations, both traditional STEM powers and new emerging players, have made substantial investments in STEM, yielding a new dynamic global distribution of human and financial resources, facilities, publications, patents, and technology transfer. In this atmosphere, it is little surprise that all but two of the last 15 Nobel Prizes in Physics, Chemistry, and Physiology/Medicine have gone to international teams of researchers. The United States, by virtue of strong STEM investments over the past 50 years and the size of its STEM community and economy, still leads in most of these categories. In many areas (e.g., total government STEM

[20] National Science Foundation Science and Engineering Indicators, 2014, http://www.nsf.gov/statistics/seind14/

[21] PCAST Report, Transformation and Opportunity: The Future of the U.S. Research Enterprise, 2012, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_future_research_enterprise_20121130.pdf

[22] "The New Map of Science". Special Section, *Nature*. October 2012. http://www.nature.com/news/specials/global/index.html

[23] UK Royal Society Report: Knowledge, Nations, Networks. 2011, http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2011/4294976134.pdf

[24] UNESCO Science Report, 2010, http://www.unesco.org/new/en/natural-sciences/science-technology/prospective-studies/unesco-science-report/

[25] The use of STEM vs. STI reflects differences in perspective on economic integration. U.S. HEI typically uses "STEM", reflecting a well-accepted, education-based term, while the State Department and many other nations have for several years been using the parlance of international "STI" engagement, making a direct link between science and technology and the innovation that is essential for economic growth. We will use STEM, but have in mind the same link to economic factors.

investment, recipient of foreign students, publications[26]), however, the U.S. proportion of the world total has fallen dramatically in the last ten years, yielding a new map of science that is increasingly multipolar.

The past decade has also seen striking increases in science diplomacy efforts, both by the United States, as well as many other nations. Science diplomacy has many facets, but for the purpose of this article we focus on "science for diplomacy" (and not on the "science in diplomacy" nor on the "diplomacy for science"[27].) Simply put, science diplomacy is the use of scientific activities to build and strengthen relationships between countries. Several recent U.S. presidents, including President Obama (e.g., in his 2011 Cairo speech[28]), have identified science diplomacy as an important way to build positive bilateral relationships, and also to contribute to solving global challenges that no one nation can solve alone. The number of government-to-government bilateral Science and Technology Agreements, which serve to facilitate STI cooperation, has more than doubled increased in the decade 2001 to 2012[29]. Numerous countries have embraced such science diplomacy as an essential part of their foreign policy[30], there have been large international meetings on the topic[31]), AAAS debuted a new on-line quarterly journal *Science & Diplomacy* in 2012[32], and diplomatic science diplomacy networks have recently been established and/or strengthened by countries such as Switzerland[33] and the United Kingdom[34].

Members of the U.S. academic community play an important role in enhancing U.S. science diplomacy as they welcome international students and researchers into their labs, conduct world class research and education projects with their international collaborators both in the United States and abroad, and open campuses and centers across the world, all the while carrying U.S. values and standards of excellence and accountability.

Science diplomacy contributes to U.S. "soft power"[35] by improving the opinion that leaders and peoples around the world hold of the United States. The Pew Global Attitudes Project[36] documented that people worldwide admire the United States for its science and

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[26] National Science Foundation Science and Engineering Indicators, 2014, http://www.nsf.gov/statistics/seind14/

[27] AAAS and UK Royal Society Report, 2010: New Frontiers in Science Diplomacy http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2010/4294969468.pdf

[28] Obama, B.H. "A New Beginning." Speech delivered in Cairo, Egypt. June 4, 2009. http://www.whitehouse.gov/blog/NewBeginning/transcripts

[29] "Science and Technology Agreements as Tools for Science Diplomacy: A U.S. Case Study." Bridget M. Dolan. 2012. http://www.sciencediplomacy.org/files/science_and_technology_agreements_as_tools_for_science_diplomacy_science__diplomacy.pdf

[30] "Science diplomacy at the intersection of S&T policies and foreign affairs: toward a typology of national approaches", Tim Flink and Ulrich Shreiterer, *Science and Public Policy*, 2010, http://spp.oxfordjournals.org/content/37/9/665.short

[31] AAAS and UK Royal Society Report. 2010: New Frontiers in Science Diplomacy http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2010/4294969468.pdf

[32] *Science and Diplomacy,* http://www.sciencediplomacy.org/

[33] http://www.swissnex.org/

[34] http://heglobal.international.ac.uk/about/heglobal-partners/science-and-innovation-network.aspx

[35] Joseph S. Nye Jr. (2004) Soft Power: The Means to Success in World Politics, New York, N.Y.: Public Affairs ISBN: 978-1-58648-225-1.

[36] Pew Global Attitudes Project: http://www.pewglobal.org/

technology at a level 22 percentage points higher than their attitude toward the United States in general. U.S. STEM researchers and students working with their international counterparts contribute to this phenomenon and also make important contributions to the global advancement of STEM research and application by sharing expertise, resources, and facilities. Given U.S. economic constraints, building strong international STEM partnerships can also be seen as a valuable adaptive approach for sustaining national STEM excellence in support of national economic, health, environment, and security issues.

2. Development of the Survey

This survey marked a new direction for the two organizations involved. AIEA members typically come from the humanities (e.g., languages, culture, and history) and social sciences (politics, anthropology, economics, and international relations), fields with great strengths that underlie many HEI efforts at comprehensive internationalization. The Department of State also has a strong legacy of working with U.S. universities in these same areas, which form the backbone of programs supported by its Bureau of Educational and Cultural Affairs. An indication of STEM-related interest, however, is the greater eligibility of those in science disciplines for many of the various Fulbright Scholars Programs. The increasing importance of STEM fields in a global context, for both the nation and its HEI, make this an auspicious time to explore this new area of mutual interest so as to understand, respond to, and enable the growing engagement of U.S. STEM faculty and students with their counterparts around the world.

AIEA

AIEA[37] was formed in 1982 to provide a leadership voice on significant issues within international higher education, promote international programming and administration within HEI, and establish a professional network among international higher education's institutional leaders. It has both individual and institutional memberships. Individual members are institutional leaders, many occupying a position known generically as the Senior International Officer (SIO). Although international responsibilities are organized in different ways on different campuses, SIOs are often responsible for study abroad, international students on campus, and strategic global engagement (e.g., curriculum internationalization, faculty research, institutional partnerships, joint or dual degrees, international centers and foreign campuses.) AIEA has 269 member institutions, 87% of which are universities, including 77% of the institutions in the Association of American Universities (an organization that includes 60 of the top research institutions in the United States). AIEA membership also includes dozens of HEI outside the U.S., although these were not included in the survey.

U.S. Department of State

[37] AIEA website: http://www.aieaworld.org/

The U.S. Department of State[38], the oldest Executive Branch Cabinet-level Department, has the mandate of managing "the nation's relationships with foreign governments, international organizations, and the people of other countries. The management of all of these relationships is called diplomacy. State Department diplomats carry out the President's foreign policy and help build a more free, prosperous, and secure world."[39] Science and technology influence many dimensions of diplomacy, and much of that work is undertaken by two units. The Bureau of Oceans and International Environmental and Scientific Affairs (OES) manages bilateral and multilateral government-government science relationships as well as scientific and environmental agreements and treaties. The Office of the Science and Technology Adviser to the Secretary (STAS) works on science, technology and innovation policy issues across the entire Department and also works with the U.S. broader scientific community, including managing several fellowship programs that bring many scientists and engineers to serve in the Department[40].

A sister agency is the U.S. Agency for International Development (USAID), which provides U.S. foreign assistance with the twofold purpose of furthering America's interests while improving lives in the developing world. USAID has long funded projects at U.S. HEI to assist in its mission. USAID recently launched The Global Development Lab[41] (which includes what was formerly called the Office of Science and Technology) to spearhead science and engineering approaches to discover, test, and scale breakthrough development solutions across the Agency.[42]

Survey

During fall 2012, an AIEA task force, with input from the two authors of this article, developed a 15-question survey designed to probe the nature of STEM internationalization at U.S. HEI and to understand how such efforts can be enhanced and supported.[43] In December 2012 AIEA sent the survey electronically to all of its members, with one response per institution requested by mid-January 2013. The survey yielded 114 responses. No effort was made to collect information that could link respondents and their institutions.

The responding institutions, which all had significant curricular offerings in STEM fields, were heavily weighted toward doctoral universities (65.7%, with 17.1% Masters universities, 14.3% 4-year colleges, and 1.9% community colleges). This distribution generally reflects the membership composition of AIEA, which is weighted toward larger institutions with formal SIO positions. For most questions there were not marked differences among these different kinds of

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[38] Department of State website: http://www.state.gov/
[39] http://www.state.gov/r/pa/ei/rls/dos/107330.htm
[40] Jefferson Science Fellow are senior faculty; AAAS Fellows can be junior or senior scientists or engineers. http://www.state.gov/e/stas/fi/index.htm
[41] The Global Development Lab website: http://www.usaid.gov/GlobalDevLab
[42] http://www.usaid.gov/who-we-are/organization/independent-offices/office-science-and-technology
[43] The task force included Darla Deardorff (Duke U), Diana Davies (Princeton U), Christa Olson and Pramad Mahajan (Drake U), David Fleshler (Case Western U), Sabine Klahr (U of Utah), William Lacy (U California-Davis), Andrew Gillespie (Auburn U), Steven Hanson (College of William and Mary), Donna Scarboro (George Washington U), Richard Nader (U of North Texas).

institutions; we note the few places where these were striking. All offered degrees in various STEM fields.

Survey Results

3. Institutional Priorities and Goals

Three questions were directed at understanding the role that STEM plays in overall institutional plans concerning internationalization and at the criteria institutions use for deciding upon international STEM investments.

a. Strategic international plans

Over half (60.8%) the respondents indicated their institutions had a strategic international plan. This is slightly higher than the pattern (55%) documented by the 2012 ACE Mapping Internationalization on U.S. Campuses[44], perhaps reflecting that AIEA institutions tend to have a strong interest in internationalization. Even for those institutions that did have a strategic international plan, however, not all these plans explicitly addressed STEM fields. In almost 45% of the plans, STEM fields were not explicitly mentioned; in 49% they were explicitly mentioned but not prominent; and in only 6.7% of the plans were STEM fields explicitly mentioned and prominent. Most of the strategic international plans did not include reference to technology transfer units (79%), and in only 4.7% were technology transfer units explicitly mentioned and prominent.

Summing across these measures, in only about one-third of institutions (49% of 66.7%) are there strategic international plans that explicitly mention STEM fields at all, and in only a handful of internationalization plans (roughly 4%; 6.7% of 60.8%) are STEM fields prominently included.

b. Institutional Criteria for STEM-specific investments

Over half the institutions surveyed (55.7%) do not have explicit criteria for making decisions on investments of its resources for international purposes. Of those that do have such criteria, only 22% articulate specific STEM criteria, in addition to more general criteria. .

In short, despite the internationally collaborative nature of STEM fields today, STEM activities and concerns do not appear to have a very active role in the ways U.S. institutions have strategically conceived internationalization thus far.

4. Types of International STEM Activity

[44] Mapping Internationalization on U.S. Campuses, 2012, http://www.acenet.edu/news-room/Pages/2012-Mapping-Internationalization-on-U-S--Campuses.aspx

Three questions asked respondents to identify and characterize the various types of international STEM activities being undertaken on their campuses.

a. Internationalization in STEM Departments

Table 1 demonstrates that STEM departments, especially at research institutions, are most likely to be internationally engaged through direct interaction with international students and international colleagues in their labs and research collaborations.

On the educational side, STEM students from baccalaureate colleges were twice as likely to study abroad as their peers from research universities, although compared to students in non-STEM fields their participation is still quite low (21.1% of the total study abroad numbers for the U.S. in the last Open Doors report). Very few institutions reported internationalization via changes to their science curriculum, international STEM distance learning, or STEM engagement at international branch campuses.

In short, the form of internationalization characterizing STEM fields is based on bringing together students and researchers from different countries – for the goal of pursuing STEM issues, rather than learning about each other's countries. This presents a major contrast to the forms of internationalization most discussed in the education literature and places the development of capacity for cross-cultural collaboration and shared learning as key to STEM internationalization, points to which we return in the conclusions to this article.

Table 1. International Activity in STEM departments

International Activity	***Percent institutions rating this activity as one in which "most STEM departments involved"***
Enrolling international students	67.4%
Hosting international colleagues (60% doctoral universities vs. 0% in 4-year colleges)	38.7%
International research collaborations (60% doctoral institutions vs. 6.6% 4-year colleges)	37.5%
Study abroad (twice as likely in baccalaureate colleges)	26.9%
Internationalizing their courses	5.6%
Capacity-building and development projects overseas	5.5%
Delivering courses and degrees overseas by distance means	4.3%
Participating in branch campuses overseas	2.2%
Running research centers overseas	2.2%

b. Science Diplomacy Efforts

As shown in Table 2, when given explicit examples of what constitutes science diplomacy, more than three quarters of the responding institutions reported that they were doing this. The most common form of such activity was participation by HEI in programs funded by the Department of State (e.g., Fulbright and International Visitor Leadership Programs) and USAID. As a function of the various science diplomacy activities, more than half of the institutions reported having an impact on STEM-relevant policy or capacity in other nations, and more than 40% of the institution felt that they were advancing U.S. foreign policy objectives in STEM areas.

Table 2. Institutional Engagement in Science Diplomacy

Science Diplomacy Activity	Percentage institutions engaged
Participating in government-sponsored international science activities (e.g., Department of State Fulbright and International Visitor Programs, U.S. science delegations, U.S. participant in international science activities such as those of International Panel on Climate Change and World Health Organization)	78.3%
Participating in U.S. government-funded development projects overseas (e.g., with funding from U.S. Agency for International Development)	65.0%
Impacting or advising on STEM-relevant policy or capacity of other nations	53.3%
Advancing U.S. foreign policy objectives by working in priority countries, priority disciplines, and/or priority issues	41.7%
Strengthening science diaspora connections between foreign-born STEM personnel on your campus and their ancestral homelands	38.3%

c. International Activities and Department of State Science Diplomacy Efforts

When asked about alignment of institutional STEM objectives and the countries, disciplines or issues on which the Department of State focuses it science-related efforts, 62.3% reported there was good alignment. The institutions reporting mismatches were more often doctoral institutions (51%) than baccalaureate (11%), with the following types of issues cited:

- Countries where the State Department focus their science diplomacy efforts (e.g., where there is a bilateral government-to-government Science and Technology Agreement) were not always the countries where faculty had connections and/or interests in conducting educational and research collaborations.
- Faculty members exercised their academic freedom to conduct research not exclusively keyed to governmental priorities research areas.
- Researchers undertook international collaborations in areas of research not supported by U.S. government, e.g., stem cell research.

- Difficulties in securing visas hindered collaboration with certain countries, even on occasion in countries where there was a bilateral Science and Technology Agreement.
- Universities and colleges lacked information on the Department of State's general science-policy priorities and on the scientific foci of specific Science and Technology Agreements.

5. Challenges to internationalizing STEM engagement from outside the institution

Five questions explored the challenges that HEI have encountered in pursuing STEM internationalization. The first question was an open-ended query inviting respondents to describe challenges "specific to internationalizing research and education in STEM disciplines" at their institutions. It generated a wide range of responses. This section presents the responses where such challenges generally reflect forces external to the institution. The responses where the challenge stemmed more from conditions within the institution are presented in the next section.

a. External Challenges to STEM Internationalization

The most frequently mentioned external challenges were:

- **Curricular mandates**
  - Requirements set by outside accrediting bodies (e.g., ABET, the Accreditation Board for Engineering and Technology) that limited STEM study abroad opportunities and internationalizing of STEM curriculum;
- **Funding**
  - Preference by funding organizations for starting new research and education projects rather than sustaining existing collaborations;
  - Restrictions on many grants that allowed little funding to support the overseas partners;
- **Legal and regulatory**
  - Concerns about protection of intellectual property generated in international collaborations;
  - Complexity of Deemed Export Control restrictions, e.g., those implemented by the Department of State through its International Traffic in Arms Regulations (ITAR), by the Department of Commerce through its Export Administration Regulations (EAR) and by the Treasury Department through its Office of Foreign Assets Control (OFAC);
  - Complex requirements for research permits and work licenses that can differ across discipline and country;
  - Knowledge of and compliance with laws in countries of partners; and
- **Travel**
  - Understanding of risks when there are State Department-issued travel warnings and restrictions.

b. *U.S. Government-related Issues as Potential Challenges to STEM Internationalization*

A follow-up question to the open-ended one just discussed explicitly covered possible U.S. government-related challenges to international STEM engagement. Institutions varied considerably in the extent to which they reported such issues. The results in Table 3 indicate that for most of the 84 institutions that responded to this question, most of these issues constituted very minor barriers or no barrier at all.

Table 3. Barriers to international STEM Engagement

Issue	**Percent institutions** "***Very minor barrier***" or "***Not a barrier at all***"	**Percent institutions** **"*Very serious barrier*" or "*Serious barrier*"**
Human subjects issues, ethics, research integrity	61.3%	3.9%
Security of personnel	58.0%	1.2%
Security of equipment and data	55.5%	8.6%
State Department travel warnings	51.2%	7.1%
Deemed export control, ITAR	50.7%	16.9%
Intellectual property rights	48.1%	13.9%
Legal issues	45.6%	16.5%
Visas for foreign students, faculty and/or visitors	25.0%	21.4%

However, Table 3 also demonstrates that for more than 15% of institutions, visas, legal issues and Deemed Export Control/ITAR issues were reported as "Very serious" or "Serious" barriers to international STEM engagement; these respondents were heavily weighted towards doctoral institutions.

c. Visa issues

Ongoing concerns of the U.S. scientific community about visas for foreign-born students and researchers (e.g., the 2009 letter from 39 scientific societies regarding "Visas Problems Harming America's Scientific, Economic and Security Interests"[45]) led us to pose three detailed questions about possible visa issues encountered by U.S. HEI. Regarding the nature of visa issues, the most commonly cited occurrences were "First visa delays" (63.2% of institutions), "Visa denials" (44.7%), and "Re-entry/re-issued visas" (34.2%), while 22.4% of institutions reported no visa problems.

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[45] "Statement and Recommendations on Visa Problems Harming America's Scientific, Economic, and Security Interests". 2009. http://www.aaas.org/news/releases/2004/0512visa.pdf

In response to a question about the frequency of such visa issues, 47.4% of institutions indicated visa issues occurred fewer than 5 times per year, 25% reported 5-10 issues per year and 9.2% reported more than 10 such issues per year.

Finally, in terms of the "Overall impact of any visas problems for STEM applicants, research, teaching and programs", 27.9% of institutions found them to be "Not a problem", 31.7% indicated they were "Inconvenient", the same percentage found them "Moderately disruptive", while 8.9% of institutions found these issues to be "Highly disruptive". No baccalaureate institution reported either moderate or high levels of disruption, while 47% doctoral institutions found the visa issues to be moderately or highly disruptive.

These results, like those about challenges in general, demonstrate that there is important variation between institutions especially in the frequency and impact of such visa issues, with some doctoral universities experiencing frequent and moderately or highly disruptive consequences.

6. Challenges to internationalizing STEM engagement from within the institution

Quite surprisingly to us, the majority of responses to the open-ended question on possible barriers to STEM internationalization cited challenges that were internal to their institutions, rather than external. While this was not the initial focus of the survey, the depth of responses on this subject warrants examination. The most frequently mentioned responses to this open-ended question:

- **Curriculum**
  - Institutional/department requirements that limit what students can do; and
  - Few study abroad alternatives to Junior Year Abroad, which does not work well for many STEM students.
- "**STEM culture"**
  - Faculty who have a strong desire to keep graduate and undergraduate students working in on-campus labs, both to provide a high-quality experience and to keep faculty research projects going; and
  - STEM students and faculty who have a narrow focus on their specific research questions, not necessarily seeing the added value of international learning or collaboration.
- **Uncertainty about international partnerships** with regard to:
  - Quality of international STEM partners – faculty, labs, courses, course equivalencies, level of innovation;
  - Ethical and IRB issues, research infrastructure, and treatment of women; and
  - Difficulty in finding appropriate international partners, appropriate ways to develop and sustain partnerships.
- **Funding**
  - Too little funding for faculty travel, housing, and other costs connected to visiting partner institutions;
  - Too little funding for hosting visitors from partner institutions; and
  - Difficulties with such issues as tuition waivers, faculty exchange costs, MOUs.

- **Institutional demands and incentives**
    - Faculty reward structures that do not value international activities; and
    - Heavy teaching loads and/or heavy research demands that leave no time for international activities.
- **Infrequent inclusion of STEM in university internationalization efforts,** due to
    - Little international office or institutional knowledge of what STEM faculty are doing internationally;
    - Rare request by the international office to STEM units to participate in internationalization efforts; and
    - Lack of awareness by STEM faculty of international initiatives of the institution.
- **Language and culture**
    - Lack of language skills needed for collaboration on the part of STEM faculty.

7. Strengthening U.S. HEI STEM engagement

The survey ended with two questions about ways that organizations including the U.S. government might strengthen international STEM engagement by U.S. HEI.

a. Information relevant to international science engagement

There was strong interest across institutions in having access to various types of international science information, with than 95% of respondents indicating they would find more such information "very useful" or "somewhat useful". Universities expressed stronger interest in this kind of information than did four-year colleges.

Type of information	Percentage institutions: "very useful"	Percentage institutions: "somewhat useful"
U.S. Department of State science-related public diplomacy priorities	73.6%	23.6%
Country-specific guides to higher education and research	71.6%	28.4%
Scientific investments and priorities of other nations	71.6%	27.0%
International STEM futures and horizon-scanning work	62.5%	33.3%
Major international STEM activities of other U.S. universities	60.3%	39.7%

b. HEI Survey Responses regarding the Department of State and international STEM engagement

The survey yielded a wide range of responses to the following open-ended question "Keeping in mind that the U.S. Department of State is not a funding agency, but can convene government agencies, international science counterparts, universities, private sector groups, and others, what key actions could the Department of State do to strengthen international STEM engagement by your institution?"

The most common responses fell into the following categories:

- ***Facilitate international collaboration*** with institutions abroad on both institutional and faculty levels by disseminating information and models of collaboration that bring U.S. and non-U.S. STEM faculty together, with specific attention that could:
  - Enable longer-term relationship building as much as one-off short-term projects;
  - Allow a focus around a particular theme or problem, especially in connecting STEM issues to entrepreneurship; and
  - Focus attention on how to support international partners in low-income countries.
- ***Work to further diminish visa delays*** and so lower barriers to travel
  - Address issues for both outgoing and incoming scientists and students; and
  - Consider creating an academic "fast track system" for STEM collaborations;
- ***Strengthen outreach to and engagement of the U.S. academic STEM community***
  - Share information on opportunities for science diplomacy, with examples of good projects and attention to sharing this kind of work to the public;
  - Actively engage U.S. HEI on how they might "bust barriers" and so more easily comply with U.S. government regulations and policies;
  - Encourage State Department staff to attend and make presentations at disciplinary conferences in STEM fields; and
  - Reach out to all types of U.S. institutions, not just large, prestigious research centers.
- ***Work to increase government-wide support for and direction in international STEM engagement***
  - Work with other parts of the U.S. government to develop and/or articulate a more integrated national approach to international STEM engagement.

8. Conclusions

An important finding of the survey is that even as U.S. HEI have been increasingly engaged in internationalization, few appear to have institution-wide international plans or articulated goals in the STEM areas. This generally mirrors the national approach to international scientific collaboration, at least when it comes to much university-based research. It tends to be science-driven and reflect a "bottom-up", faculty-initiated, decentralized approach. Research conducted at U.S. national labs and within U.S. government science agencies can be more mission-based and more "top-down", as is the case in university- and government-conducted STEM work in many other countries[46]. U.S. universities have long served as platforms for enabling international collaboration in science, but as noted by several of the respondents, SIOs often are not aware of where all of their STEM faculty members are working around the world. This leads to a caveat as we consider the results of the survey. Given the decentralized approach to international science engagement, it is not known whether the survey respondents conferred

[46] EU Report on Drivers of International Research Collaboration, 2009, http://ec.europa.eu/research/iscp/pdf/drivers_sti.pdf

across campus, with science faculty or with Vice Presidents for Research, in preparing the response. Thus the responses may underestimate the nature or degree of STEM internationalization at the responding institutions; conversely, AIEA member institutions have a strong commitment to internationalization, so our results may overestimate the degree of STEM internationalization across the full range of U.S. HEI.

Even with these caveats, the survey demonstrates that there is a set of U.S. HEI with strong international STEM engagements and that many of their activities are likely enhancing U.S. science diplomacy. These results match the experience of State Department science policy officials, who in their travels around the world learn of and visit many U.S. STEM collaborations and see how such cooperation strengthens our nation's bilateral relationships and generates tremendous goodwill towards the United States. The survey shows that U.S. HEI recognize State Department programs as the most common contributions to science diplomacy. However, such programs appear to constitute a fraction of those engaged in international STEM collaboration. Data from the International Institute of Education's Open Doors Report[47] indicate that overall in the 2011-2012 academic year, more than 55,000 U.S. students in STEM fields studied abroad. Various Fulbright programs supported approximately 1200 U.S. STEM students (more than 30% of total students) for exchanges in 2012, Boren Awards for International Scholars and Fellows supported 40 STEM students (approximately 15% of total) in 2013[48], and the Benjamin A. Gilman International Scholarship program, typically supports more than 2,500 students per year with approximately 22% being STEM students. More than 500 Fulbright Scholars (more than 25% of total scholars) were in STEM fields in 2012[49] while over 57,000 U.S. academic authors co-published scientific papers with international co-authors in 2012[50].

These figures suggest that much of the STEM people-to-people interaction and research cooperation that is an important positive contributor to U.S. international scientific relationships is not funded or directed by the primary U.S. diplomatic agency. Thus in order to better understand the nature, magnitude, and impact of academic STEM engagement on U.S. relationships with other nations, it may be valuable to consider a broader definition of science diplomacy that includes both directly supported activities as well as such undirected activities. Further insight might be gained by examining the magnitude and impact of such undirected STEM engagement activities for the United States vs. for other countries where the higher education system is part of the national government and where international STEM engagement is often directed by the government for specific national goals, including economic development

[47] Estimate derived from International Institute of Education, Open Doors 2013, http://www.iie.org/Research-and-Publications/Open-Doors/Data/US-Study-Abroad/Fields-of-Study/2001-12
[48] National Security Education Program 2013 Annual Report: http://www.nsep.gov/docs/2013-NSEP-Annual-Report.pdf
[49] http://www.cies.org/fulbright-scholars
[50] National Science Foundation Science and Engineering Indicators, 2014, http://www.nsf.gov/statistics/seind14/content/chapter-5/chapter-5.pdf

and diplomacy[51]. This would contribute to the nascent field of the "science of science diplomacy".

The absence of STEM disciplines from many HEI strategic international plans and the dearth of criteria for international STEM investment criteria also suggest that HEI themselves are not typically directing these STEM international activities for diplomatic ends. Rather, such positive contributions to science diplomacy, as more broadly defined, are most likely the byproduct of overlapping goals and basic values (e.g., excellence, evidence-based progress, transparency, accountability, inclusion, national service) of U.S. diplomatic agencies and HEI. In many cases, we conclude, an HEI's impact on science diplomacy is the sum of institution-, department-, and individual-level STEM engagements largely undertaken by "unintentional diplomats", i.e., STEM faculty and students intent on advancing science while serving unknowingly as "science ambassadors" for the United States.

Two hallmarks of U.S. higher education are limited federal government involvement and freedom of speech afforded to HEI communities[52]. Therefore it should not come as a surprise that there are times when the actions of HEI do not coincide with the priorities of the Department of State. Many research projects might require a longer duration than might suit political timeframes[53]. The integrity of some research projects may require independence from national political objectives (e.g., one cannot objectively study the interaction of science and society if one is associated with U.S. efforts to strengthen civil society institutions.) Survey respondents also identified the choice of country and disciplinary focal area as areas of potential mismatch. Such choices can result when academics act on strictly scientific criteria to form the best science collaborations. The case of U.S. universities partnering internationally on stem-cell research demonstrates that U.S. HEI are free to pursue their own goals and objectives, finding foreign partners and foreign funding for scientific research even in areas that are not U.S. government priorities.

The survey also documented wide variation across HEI in STEM engagement, science diplomacy and efforts to internationalize U.S. campuses. Not only are U.S. HEI not a monolithic entity, the variation among them can be viewed as a great asset in our national STEM engagement and diplomacy. Baccalaureate institutions excel at sending undergraduates overseas in study abroad, even in STEM fields, thus amplifying the people-to-people opportunities for science diplomacy. Our research universities exhibit wide variation that serves to diversify U.S. international STEM partnerships. That variation can help define an institution's unique value

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[51] EU Report on Drivers of International Research Collaboration, 2009, http://ec.europa.eu/research/iscp/pdf/drivers_sti.pdf

[52] "An Overview of Higher Education in the United States: Diversity, Access, and the Role of the Marketplace". Peter D. Eckel and Jacqueline E. King. 2004. American Council on Education: http://www.acenet.edu/news-room/Documents/Overview-of-Higher-Education-in-the-United-States-Diversity-Access-and-the-Role-of-the-Marketplace-2004.pdf

[53] "Science diplomacy at the intersection of S&T policies and foreign affairs: toward a typology of national approaches", Tim Flink and Ulrich Shreiterer, *Science and Public Policy*, 2010, http://spp.oxfordjournals.org/content/37/9/665.short

proposition within a global context (e.g., based on U.S. geographic location, research and teaching strengths, diaspora and demographic history, legacy of foreign faculty and alumni, civic, spiritual, and/or service mission, and partnerships with nearby multinational corporations). It also greatly enriches the nation's potential for international scientific engagement. Such variation suggests that different needs and challenges of different types of institutions be considered in national efforts to strengthen U.S. international STEM engagement.

The survey documented little international HEI engagement of their "innovation ecosystems" and technology transfer units while the Department of State has been in recent years actively pursuing "economic statecraft", i.e., strengthening both the international engagement of U.S. industry and innovation systems as well as the economic enterprises of countries around the world. At a time when many U.S. universities, particularly the public ones, have been given an added "fourth mission", i.e., a mandate to stoke the engines of local and state economies[54], these results suggest an area of opportunity where universities can use their international STEM engagements to help serve as an economic drivers within a more globalized economy.

Turning in an inward direction, the survey also made clear that the international engagement of STEM fields has a distinctive role to play within the overall internationalization efforts of HEI, but that this was little recognized as of yet. The fact that STEM internationalization has taken a collaborative form markedly different from that of many but not all other fields has obscured this role and perhaps contributed to a situation in which STEM fields are given a minor position in most institutional internationalization plans. Although many international exchange programs have existed for decades (e.g., the Fulbright exchange programs which were created to promote mutual understanding), for many years much international education in the U.S. focused on ***learning about other nations and cultures***, rather than ***doing research or learning with them***. Over the last 15 years or so, however, latter activity has risen to the same level as the first, and here is where the collaborative nature of STEM internationalization can make a significant contribution to institutional efforts.

The internationalization of HEI is increasingly seen as an internationally collaborative endeavor[55] where institutions are striving to find mutual benefit.[56] U.S. institutions are devoting a great deal of attention to enhancing the abilities of their students to engage in cross-cultural interactions and to forming sustained and meaningful institutional partnerships with HEI and other organizations overseas. In this light, on the most recent ACE Mapping Survey, 90% of doctoral institutions and 50% of baccalaureate ones reported that they have greatly increased

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[54] Tapping the Riches of Science: Universities and the Promise of Economic Growth, Roger L. Geiger and Creso M. Sá. 2009. Harvard University Press.

[55] S.B. Sutton 2013 "The Growing World of Collaborative Internationalization: Taking Partnerships to the Next Level" *IIE Networker* Fall 2013, pp. 40-41.

[56] P. M. Peterson and R.M. Helms. 2013. Challenges and Opportunities for the Global Engagement of Higher Education. Presented at the Beijing Forum. http://www.acenet.edu/news-room/Documents/CIGE-Insights-2014-Challenges-Opps-Global-Engagement.pdf

their international partnership activity over the last five years. The very activity that is at the heart of STEM internationalization is now at the heart of institutional internationalization.

The expertise that STEM faculty and students have already developed concerning such collaboration can be tapped as institutions move toward greater use of international partnerships. In return, the value of framing such collaborations with the deep knowledge of countries, languages, intercultural dynamics, and global connections that has long been at the heart of traditional forms of international higher education can enhance what is happening in the STEM fields.

While the survey did not explicitly probe how HEI can support STEM fields more directly in their international engagement, this issue emerged strongly in the open-ended responses. The many internal challenges identified by respondents also, however, illustrated how the all-too-common gulf between international offices and STEM disciplines might be bridged. First and foremost, international offices and STEM departments could benefit from deeper conversation with each other, learning about the goals and international connections that each is pursuing and how these might support each other[57]. Second, there could be greater attention, staffing, and funding directed toward facilitating international collaboration: removing procedural difficulties that limit faculty exchange, supporting the development of new collaborations in their early stages (before they are ready to seek external funding), guiding the process of making commitments and signing agreements, etc. Third, international offices can develop study abroad options that suit the curricular demands of STEM fields in terms of timing and topic. Fourth, such offices can also explore the value added to STEM education and research by more explicit attention to matters of cross-cultural interaction and understanding, both in the laboratory and more generally – developing workshops, language immersion options, and interdisciplinary course clusters that make this possible. Finally, HEI can make clear to members of both state and national legislatures the internationally collaborative nature of STEM work, and the need to support such collaborations for the advancement of science and the people-to-people diplomacy that comes with this.

The survey documented the strong interest from HEI in greater international STEM engagement. Because scientific knowledge is now more dispersed around the world, the value of international networks is critical both to U.S. universities and to the nation. Universities are keen to serve as vibrant global hubs where their STEM students and faculty are engaging bidirectionally across the world, adding scientific and educational value by bringing U.S. local knowledge to a global sphere, **and** by working with international collaborators to bring global

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[57] Such deeper conversations were the theme of a recent AIEA Thematic Forum "Developing Institutional Strategies for Growing Global Research" co-organized by the University of North Texas and the University of South Florida, held at the latter in April, 2014. http://global.usf.edu/globalforum/

knowledge back and integrating it into U.S.-based activities[58]. International STEM engagement may also represent a new growth opportunity for HEI internationalization at a time of cuts to Department of Education Title VI funds for international education grants[59] and cutbacks in funding for some public HEI. Such enhanced international STEM engagement can be viewed as a tremendous opportunity; it not only enlarges the platform on which much science diplomacy can be conducted, but it also advances larger national interests. U.S. strength in science and technology is enhanced when our national research enterprise, much of it embedded in our universities, develops partnerships and networks that leverage resources, expertise, facilities and phenomena, around the world.

There are multiple ways that the Department of State, which is not a science funding agency, helps to facilitate international academic STEM engagement. First, many of the more than 50 government-government Science and Technology Agreements managed by the Department of State foster academic collaboration both by convening government agencies that fund academic science collaboration and also by including language that protects intellectual property, establishes benefit sharing, and prevent taxation of research equipment. Although these Agreements can identify a few focal areas of scientific cooperation, they are not meant to focus the broader academic scientific collaboration in a top-down manner; rather, these Agreements are intended to facilitate the rich and diffuse bottom-up collaboration that characterizes much of American's international academic collaboration in science areas. Second, the Department of State strives to foster a better environment for science in many countries by infusing its diplomatic activities with specific science policy priorities including advancing women in science, fostering innovation, and enhancing public understanding of the role of science in society[60]. Third, through the multiple programs of its Bureau of Educational and Cultural Affairs, the Department supports thousands of U.S. and foreign STEM faculty and students to participate in teaching and research exchanges every year. Fourth, as a convener and catalyst at the national/international boundary, the Department of State seeks to strengthen academic STEM networks in multiple ways, for example via its activities in the Networks of Diasporas in Engineering and Science (NODES[61]) partnership and by building on the great strengths of its ECA programs (e.g., the Fulbright alumni networks). Fifth, the Department of State has also made advances in achieving its 2010 promise to integrate international activities across the Department of State, USAID, and other federal agencies.[62] For example, a new post-doctoral researcher program has been developed between the Fulbright Scholar Program and the

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[58] The New Invisible College. Caroline L. Wagner. 2008. The Brookings Institution.
[59] L. Nelson. 2011. Big Cuts to International Education. *Inside Higher Education*.
http://www.insidehighered.com/news/2011/04/15/international_education_takes_hit_in_2011_budget
[60] From the Department of State's Office of Science and Technology Cooperation website:
http://www.state.gov/e/oes/stc/index.htm .
[61] NODES; http://www.aaas.org/program/science-and-engineering-diasporas
[62] Quadrennial Diplomacy and Development Review: Leading Through Civilian Power. Department of State. 2010.
http://www.state.gov/documents/organization/153108.pdf

National Institutes of Health[63]. Germane to issues raised in the survey, State has worked with its sister agency USAID, in support of the USAID-NSF Partnerships for Enhanced Engagement in Research (PEER) Science program and the USAID-NIH PEER Health program, both of which can support foreign country partners in STEM collaborations in less developed countries where USAID works[64]. The Global Development Lab at USAID has also championed several new and exciting ways to engage HEI in innovative development activities, such as the Higher Education Solutions Network[65] and Grand Challenges for Development.[66] The survey results also bring into focus an opportunity for enhanced communication on issues such as visas, intellectual property, export control regulations, and other policy and legal issues, where the balance between safeguarding homeland security and boosting international science collaboration appears to disproportionally affect our large research universities.

The survey reflects an HEI thirst for knowledge related to international STEM engagement. In response to the survey results and to better enable strategic academic STI decision-making of value to the nation, the Office of the Science and Technology Adviser at the Department of State has recently engaged stakeholders on this topic in several forums[67] [68]. These discussions have focused on how to catalyze a ***non-governmental knowledge infrastructure and platform*** that provides needed information on global STEM engagement, international science, technology and innovation opportunities and worldwide frontiers of science[69]. A key service of such a platform would be to display information provided by U.S. HEI about their own STEM activities. Many countries request assistance from the Department of State in finding U.S. STEM partners, but neither those countries nor the Department of State can easily find such information across America's more than 4,000 degree-granting HEI. A platform that displays the research and educational strengths of many U.S. and foreign HEI would enable more effective matchmaking in STEM areas. Such a platform could address other knowledge needs identified by survey respondents, for example, by disseminating both the broad U.S. government science and technology priorities developed by the White House[70] to guide actions of the Department of State and other federal agencies, as well as information about many of the State Department's international science activities, which can be found on OES and STAS

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[63] The Fulbright-Fogarty Postdoctoral Awards program: http://www.cies.org/Fulbright/Fogarty/

[64] http://sites.nationalacademies.org/pga/dsc/peer/index.htm

[65] http://www.usaid.gov/hesn

[66] http://www.usaid.gov/grandchallenges

[67] "The Role of Higher Education in Science Diplomacy: Possibilities and Potential Pitfalls", Symposium at AAAS Annual Meeting, February 2013, Boston, MA; "U.S. Looks to the Global Science, Technology and Innovation Horizon", Symposium at AAAS Annual Meeting, February 2014, Chicago, IL.; "Linking International Databases to Build Strategic Academic Partnerships in Science Workshop", May 2014, Washington, DC.

[68] Workshop on Linking International Databases to Build Strategic Academic Partnerships in Science, May 14-15, 2014. http://cns.iu.edu/workshops/event/140514.html .

[69] Colglazier, E. W. and E. E. Lyons. 2014. "The United States Looks to the Global Science, Technology and Innovation Horizon". *Science & Diplomacy,* July, 2014: http://www.sciencediplomacy.org/perspective/2014/united-states-looks-global-science-technology-and-innovation-horizon .

[70] Science and Technology Priorities for the FY 2015 Budget, Office of Science and Technology Policy (OSTP) website: http://www.whitehouse.gov/sites/default/files/microsites/ostp/fy_15_memo_m-13-16.pdf

websites[71]. Because HEI are also interested in the strengths and funding priorities of other nations, it would also be valuable if such a platform provided such information. The survey documented that HEI are also interested in emerging global science trends. Thus another valuable facet of such a global academic knowledge platform would be to connect U.S. academia with information on STI foresight (e.g., unclassified U.S. government reports[72], U.S. private sector efforts[73], efforts of the UK[74], Latin America[75], the European Union[76], Asia[77]), on horizon-scanning business activities (e.g., roadmaps[78], international technology assessments[79], private sector futures reports[80]), and on other sources of information on international science (e.g., Switzerland[81], France[82], UK[83], Australia[84], and South Korea[85]).

In conclusion, the survey provides timely information and identifies areas of potential synergy as the United States and its HEI respond to the changing terrains of global higher education and global science, technology and innovation. Just because many U.S. science faculty and students may be "unintentional science diplomats" does not mean that they or their institutions are unwilling diplomats. In fact, U.S. HEI while protective of their independence from government, also embrace national agendas, receive federal funds and conduct research in support of national objectives, and value commitment to national service. The survey results demonstrate that as we recognize and respect the mandates of American academia and government, there is much to learn and much to do to advance international STEM collaboration and science diplomacy.

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71 OES: http://www.state.gov/e/oes/ , especially its Office of Science and Technology Cooperation: http://www.state.gov/e/oes/stc/ ; Office of the Science and Technology Adviser to the Secretary: http://www.state.gov/e/stas/

72 National Intelligence Council report: Global Trends 2030: Alternative Worlds, 2013. http://www.dni.gov/files/documents/GlobalTrends_2030.pdf

73 AAAS and George Mason University launched SciCast in December 2013. https://scicast.org/aaas

74 UK Science Foresight page: http://www.bis.gov.uk/foresight

75 Inter-American Dialogue, Global Trends and Latin America's Future page: http://www.thedialogue.org/global_trends

76 Mapping Foresight: Revealing how Europe and other world regions navigate into the future. European Commission. 2009. http://ec.europa.eu/research/social-sciences/pdf/efmn-mapping-foresight_en.pdf

77 Asia-Pacific Economic Cooperation (APEC) Center for Technology Foresight: http://www.apecforesight.org/ ; The Asian Foresight Institute: http://www.asianforesightinstitute.org/index.php/eng

78 International Technology Roadmap for Semiconductors, 2012: http://www.itrs.net/home.html

79 For example, World Technology Evaluation Center: http://www.wtec.org/

80 McKinsey and Company, Disruptive Technologies report: http://www.mckinsey.com/insights/business_technology/disruptive_technologies; IBM yearly roadmaps: http://www.ibm.com/annualreport/2011/ghv/#five

81 Swissnex, http://www.swissnex.org/background

82 eTECH France, http://www.france-science.org/eTECH-France,403.html

83 "UK Science and Innovation Network Annual Report, 2011-2012." "https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/36762/BIS-Science_and_Innovation_Report_Accessible.pdf

84 Government of Australia International Collaboration: http://innovation.gov.au/science/internationalcollaboration/Pages/default.aspx

85 Korea International Cooperation Agency; http://www.koica.go.kr/english/main.html