G-Science Academies Statement 2016:

Nurturing Future Scientists

Science is a human endeavor driven by an innate desire to acquire an ever-deeper understanding of the workings of nature and to meet human needs. Throughout history, scientists have continuously increased our knowledge of the world, and their innovations and inventions have immensely improved the human condition. Present-day society relies heavily upon science-based discovery, technology, and policies – whether in information systems, energy management, or disease control. Thus, nurturing future generations of scientists is important for the development of society. How can nations best develop future generations of scientists? The major issues, outlined below, include improving education and career paths in science, encouraging social values in scientists to interact with society, and promoting a diverse workforce with opportunity for women, minorities, and scientists in developing countries. How these fundamental questions are addressed will have an enormous global impact on the future of science in and for society.

Connecting Scientists and Society

Promoting Science Education and Outreach

Science is an essential subject at all educational levels. Exposure to science at the pre-primary, primary and secondary levels is important for learning the values of evidence-based inquiry and for nurturing scientific thinking. This requires training of high-quality science teachers for all school levels and the design of attractive programs and innovative teaching methods. In higher education, students can learn to conduct research, explore specialized disciplines, and establish scientific integrity and professional principles to become responsible scientists in society. The study of science is beneficial for all students whether or not they continue on to scientific careers. Critical thinking and the scientific method should form the core of science curricula at all levels. Inquiry-Based Science Education requires active pedagogy where students become "young researchers" investigating nature and society. Interdisciplinary approaches to education instill versatility, flexibility, and creativity important for research and other careers.

A key part of science education is learning the value and means of communicating science to the general public and policymakers. Education for Sustainable Development (ESD) [*1*] aims to provide benefits for society. In ESD, science education is a form of public outreach, improving scientific literacy and understanding of basic concepts related to human wellbeing (e.g. nutrition and public health), and increasing trust in science and scientists among citizens. This and similar efforts can promote the active involvement of non-scientists in scientific activities where appropriate and even accelerate open innovation. At the same time, science outreach experiences offer opportunities for scientists, particularly those in younger generations, to be conscious of "science in society" and learn to instill science as a way of life. A societal attitude favorable to science is also essential for stakeholders outside of the scientific community to be willing to contribute support for science.

Supporting Scientific Career Development

The future of science depends on education and support for younger scientists. However, in academia the prospects for their career development are challenging. The post-doctoral research (postdoc) stage is often a bottleneck for career advancement in developed countries due to insufficient principal investigator positions, while in developing countries such positions remain limited in general. Postdocs often are hired by senior research-grant awardees to work on specific projects on a short-term basis, resulting in significant risk for their career choices. With limited academic career opportunities, the pressure to "publish or perish" for all researchers can create an adverse environment for career development, leading to dropout, or even misconduct.

Specific training and career paths need to be developed for doctoral-level researchers in economic sectors outside of academia, including industry, commerce, service, education, media, government and non-government organizations. Given diverse career paths, scientists can contribute to sectors of knowledge-based economies that place a high value on critical thinking, evidence-based decision-making, and technological and conceptual innovation. To enable alternate career paths, universities can provide young scientists with opportunities for self-assessment, learning transferable skills, and engagement with other sectors of society.

The evaluation of research productivity based on publications constitutes a series of crucial checkpoints in the career development of young scientists. The widespread indiscriminate use of single metrics (e.g. number of peer-reviewed publications or a journal's impact factor) is inappropriate for evaluation of scientists. Instead, balanced rigorous reviews by scientific experts assessing scientific production are recommended. Assessment should be based on multi-faceted criteria and research evaluation guidelines such as DORA [*2*] as well as research-related activities such as societal involvement. This would ensure scientists' productivity, creativity, and ability to take scientific risks and pursue interdisciplinary and transdisciplinary research.

Scientists' Roles and Responsibilities in Society

While the primary mission of scientists is to develop and critically examine new knowledge, and pursue innovation and social progress, they also are expected to learn, perform, and take leadership positions in other important roles and responsibilities in and for society. First, scientists certify and systematize the acquired body of scientific knowledge and transmit it to the next generation. Second, scientists educate and mentor younger colleagues of successive generations and diverse backgrounds, to ensure the propagation of scientific values including critical inquiry and thinking, broad perspectives, and high ethical standards. Third, scientists get involved in outreach activities, communicate scientific developments to the general public, and engage citizens and young people who wish to improve their understanding of science [*3*]. The implementation of science and technology by policy makers also depends on a dialogue with stakeholders in society, so that scientists can know the concerns, perspectives, and priorities of society, and contribute to policy-making by offering evidence-based information related to policy choice. A critical aspect of these exchanges is that public stakeholders must be able to trust the validity of scientific results, whereas scientists bear the responsibility of meeting these expectations. The support for science and scientists in society is based on this trust/responsibility relationship, and the scientific community is responsible for training and enforcing appropriate ethical research standards.

Creating a Diverse Global Workforce

Inclusion of Women and Minorities in Science

The healthy development of science and research communities is impossible without the participation of scientists from diverse backgrounds. Although the proportion of women scientists and those from minority groups, in terms of ethnicity, physical disabilities and other groupings, varies among countries, they are rarely represented in fair proportion, especially at higher levels within organizations and in terms of equitable compensation. This under-representation is both a pervasive social injustice and a massive loss of potential contributions to science and society. Women are in some cases better represented among younger generations of scientists, but still face severe challenges in their later career development. Among these concerns is that the critical age range for childbearing overlaps with the traditional period for career development from junior to senior positions. To mitigate this issue, parental duties can be handled by both men and women, and additional flexibility within the workplace can be promoted. The availability of child-care facilities is also important. A second problem is that more women researchers work in academia than in business enterprises [*4*] despite the increasing employment of scientists in business at a faster rate than academia in the global competition for building knowledge-based economies. Given this unfavorable situation, improvements in the working conditions for diverse researchers in both academia and industry is essential so that high-quality scientists can compete in a fair way for jobs regardless of gender or other backgrounds. Toward this goal, developing and exposing young scientists to successful peer role models for women and minorities is critical. Finally, training in cultural sensitivity is required in the scientific community along with policymaking that mitigates unconscious biases, ensures flexible timing in promotion decisions at all career stages, and protects work-life balance for all.

Supporting Scientists in Developing Countries

Science is a borderless activity and has long served as a role model for international cooperation. Many global issues remain, particularly with respect to capacity building and researcher mobility and training in developing countries, which can be adequately addressed only through effective collaboration between developed and developing countries. Bilateral and multilateral cooperative programs and partnerships between developing and developed countries, and their research universities and institutes, are strongly encouraged and can be better supported and incentivized by governments, to move from the directional depletion of human scientific resources called "brain drain" to the more equitable model of "brain connectivity and circulation". Such exchange-focused collaborations should aim at strengthening the capacity of institutions to reach a critical mass of researchers in developing countries. This should span all levels from pre-doctoral, doctoral, and post-doctoral training to independent research, to expand careers and opportunities. The formation of bilateral and multilateral programs for researcher exchange and new international institutes would enhance this pattern of mobilization. International funding and awards would also encourage younger scientists to "circulate and connect" and support for programs that enable this are needed.

Ensuring Access to Scientific Information

All researchers worldwide should have access to the academic scientific literature and opportunity to publish their own research based on its quality irrespective of their financial means. Scientific societies, research organizations, publishers and governments should collectively strive to establish a sustainable economic model to mitigate the disparities in access to scientific information and to publication opportunities in different research environments. Various ideas have been proposed for the future of academic publication that go beyond the traditional model based on journal subscriptions levied by the publishing industry. This "Open Access" principle supports free access to scientific publications by all researchers and by the public. While the merits of open access policies are appreciated, concerns remain with quality control of the peer review and publication process that can be prone to malpractice (e.g. predatory publishing) and these must be resolved. An alternate business model involves public subsidy of journal subscription fees. For scientific publications to be sustainable and beneficial to scientists, a solution to cost sharing among journals publishers, journal subscribers, authors of journal articles, and the public sector must be viable and equitable.

Recommendations by the G-Science Academies Connecting Scientists and Society

(1) Science Education

The scientific community, policy makers and society can better promote science education and prepare future scientists, and all students, with inquiring minds, critical thinking, broad perspectives and ethical integrity.

(2) Career Development

Providing positive research environments and creating opportunities for doctoral students and post-docs to learn wider subjects and skills to pursue careers in broader sectors of industry, government and education is recommended.

(3) Scientists' Assessment

The use of single metrics for scientist evaluation, such as number of publications, citations, or journal impact factor should be replaced by those reflecting the quality and importance of the science and the diverse activities of scientists.

(4) Public Communication

Prioritizing public education and communication to the public and children on scientific developments, and engaging citizens to improve their understanding of science is needed.

(5) Resource for Policy

Evidence-based advice of scientists on issues in social choice and policymaking is critically important. Policymakers can seek scientists' input on these issues, and training scientists for such purposes is necessary.

Creating a Diverse Global Workforce

(6) Women and Minority Groups

Working conditions for scientists and practices that enable diverse representation and career prospects of women and minorities in a discrimination-free environment are essential.

(7) Developing Scientific Capacity

Developed and developing countries can collaborate to strengthen global scientific capacity and mutual mobility at pre-doctoral, post-doctoral, and investigator stages.

(8) Access to Scientific Information

All scientists should have access to academic literatures and opportunities to publish their research results. Sustainable publication systems with appropriate cost-sharing should be developed.

References:

[1] UNESCO Web-page: http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/

[2] The San Francisco Declaration on Research Assessment: http://www.ascb.org/dora/

[3] InterAcademy Partnership (2016) *Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise*. New Jersey: Princeton University Press.

[4] OECD Main Science and Technology Indicators: http://www.oecd.org/sti/msti.htm

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