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Early-Career Scientists

Engaging Early-Career Scientists in Global Policy-Making

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Abstract: Pressing global challenges, such as climate change, the COVID-19 pandemic, or antibiotic resistance, require coordinated international responses guided by evidence-informed decisions. For this purpose, it is critical that scientists engage in providing insights during the decision-making process. However, the mechanisms for the engagement of scientists in policy-making are complex and vary internationally, which often poses significant challenges to their involvement. Herein, we address some of the mechanisms and barriers for scientists to engage in policy-making with a global perspective by early-career scientists. We highlight the importance of scientific academies, societies, universities, and early-career networks as stakeholders and how they can adapt their structures to actively contribute to shaping global policies, with representative examples from chemistry-related disciplines. We showcase the importance of raising awareness, providing resources and training, and leading discussions about connecting emerging scientists with global decision-makers to address societal challenges through policies.

Introduction

Society faces critical challenges on a global scale that have become particularly relevant in the 21st century.[1] These include climate change and sustainable development solutions,[2,3] global pandemics,[4] national security,[5] economic growth,[6] and new technologies, such as artificial intelligence, and their impact on the safety, well-being, and quality of life across borders.[7] Policy-makers are expected to make the best decisions on these complex issues and, therefore, have the responsibility to seek the perspectives of diverse experts on these topics before taking appropriate actions.[8,9] To remain well-informed, they consult diverse perspectives and work with experts.[10,11] Scientists can play a vital role in this process, providing evidence-informed recommendations and advice. In particular, scientists offer expertise in their research fields and are more broadly trained in ways that allow them to provide insights on a wider range of topics, including data analysis, hypothesis testing, and multidisciplinary collaboration. A dialogue between scientists and policy-makers should be based on ethical principles, mutual understanding, and respect;[12,13] yet this relationship has evolved throughout history.[14] While scientific knowledge has led to innovations that have greatly benefited humankind,[15] more could be accomplished if decision-makers consistently engage and integrate scientific knowledge. However, formal mechanisms for collaboration between scientists and policy-makers are elusive and often lacking, preventing an effective dialogue and evidence-informed actions in the global decision-making process. The development of scientific knowledge and its applications in society strongly depend on policy decisions.[16] Mechanisms are therefore needed to raise awareness, build capacity, provide training, recognize policy work in job promotions, and enable sustainable engagement of scientists.[17–19] This is particularly relevant for emerging scientists, who will face the most severe consequences of actions not taken today.[19] In general, the scientific community and decision-makers should be key drivers in

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defining coherent and feasible strategies to promote the engagement of scientific stakeholders in policy-making. These include the mobilization of resources towards engaging scientists in an open, trusted, and constructive exchange, working together to seek strength and support of science for the benefit of society.[20] Some advantages of a trusted relationship between science and politics have been reflected in historical achievements, such as developing a COVID-19 vaccine in record time.[21] Herein, we address the importance of engaging scientists in policy by providing insights into the mechanisms of policy-making worldwide and identifying key stakeholders, without the aim of

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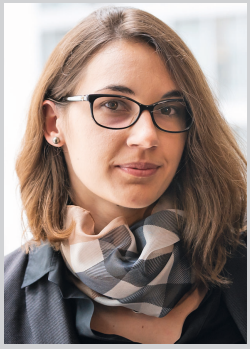

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providing a comprehensive overview. We also address major barriers to engagement and highlight the importance of scientific academies, societies, universities, and early-career networks and how they can adapt their structures to support the engagement of early-career scientists. We showcase the importance of raising awareness and enabling the adequate training of scientists to influence policy-making, with representative examples from chemistry-related disciplines, and conclude with some recommendations. We aim to provide selected resources for the scientific community while highlighting the potential of scientific networks in addressing global challenges.

Stakeholders and Mechanisms

Close relationships between scientists and policy-makers are a key element of the science-policy interface (Figure 1).[22] *Science for policy* describes the use of scientific evidence to make informed policy decisions,[23] while *science for diplomacy* relates to science collaborations to improve international relations.[24] Within a democratic society, there are many players involved in the policy-making process with different levels of expertise, interests, and perspectives, including policy-makers, investors, employees, communities, governments, academies, and other associations.[22,25,26] Industrial, academic, and governmental bodies can be identified as three major institutional stakeholders,[27] and their scientific advice is plural and biased, making it a complex process for policy-makers. We provide a selection of institutional examples to illustrate some of the global instruments and mechanisms, which are selected to represent relevant organizations and projects from different world regions.

The policy decision-making arena is distinct from typical processes in academia.[28] The implementation of expert advice depends on the foresight of decision-makers,[29] as well as structural and political patterns of government and administration, particularly in crisis situations, and differs between countries.[30] To ensure the sustainability of initiatives in the short-, medium-, and long-term, several public instruments are developed that we know as "public policy".[31] However, in 2012, the United Nations Environment Programme (UNEP, detailed in Info Box 1) report "21 Issues for the 21st Century" listed "Broken Bridges: Reconnecting Science and Policy" as a cross-cutting emerging issue for sustainability in the 21st century.[32] To this end, Lasswell made a multidisciplinary proposal to foster the link between government and society, highlighting the role of science, technology, and experts.[33] The proposal imagined that policy scientists include rationality in their decision-making and act as mediators between specialized experts and policy-makers.[33]

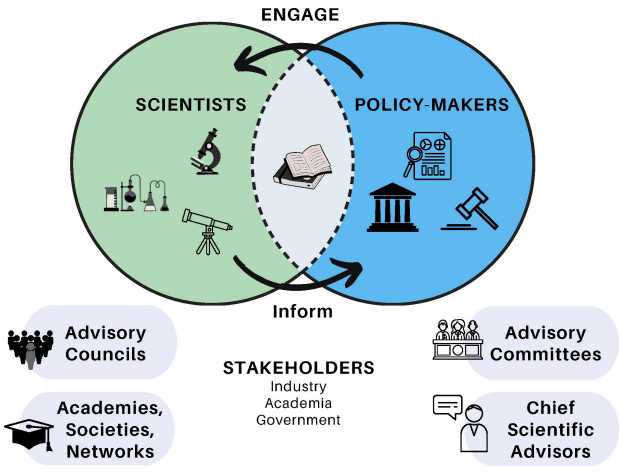

Figure 1. Overview of the science-policy interface and the role of stakeholders in shaping the policy-making process.

Info Box 1. The United Nations Environment Programme (UNEP) was established as an authority to set the environmental agenda and advocate for environmental issues worldwide.[34] The UNEP Major Group for Children and Youth (MGCY) was established as an initiative to develop a formal mechanism for involving children and young people in environmental governance and conservation processes at the UN.[35] UNEP-MGCY is currently engaged in mobilizing youth at various international, regional, and local conferences and events, including the United Nations Environment Assembly (UNEA), the Local Youth Environment Assembly (LYEA), and Stockholm+50 events, among others. It also has several working groups on various topics, including chemicals and waste, ecosystem restoration, and environmental law, through which its members can influence policy-making by introducing significant interventions on various proposals. Statements are developed for multiple events to include the voice of the youth.

Depending on how they integrate into the process, scientists can assume varying roles in policy-making.[36] They must have scientific expertise, political insight, and an understanding of policy dynamics to impact policy-making effectively. As knowledge brokers, they navigate the intersection of science and policy.[13] Pielke suggests classifying scientists according to their orientation towards expanding or reducing decision-makers' options into honest brokers and issue advocates.[37] Although scientists who act as honest brokers or neutral experts may have greater credibility among decision-makers,[38] those who advocate for their agenda or coalition may have more influence on policy implementation.[39] Conversely, scientists who remain on the periphery of political debates and act as neutral experts can be considered scientific arbiters.[37] The role that scientists play in the science-policy interface depends on their function. For instance, a scientific advisor in a ministry should uphold principles such as neutrality, independence, and legitimacy,[13] and act as an honest broker providing scientific findings to advocates and policy-makers,[40] rather than being an issue advocate. Nonetheless, an issue advocate can be instrumental in positioning certain topics on the political agenda.[41] Finally, it is important to note that some scientists may defend particular interests behind a facade of science,[42,43] and such stealth issue advocates may do more

harm than good to the standing of science in policy. According to Pielke, a "pure scientist", i.e., someone who does not get involved in politics, does barely exist.[37] Political actors can use scientific knowledge for their strategic purposes; in these cases, scientists have an orientational role where their knowledge is used to argue against an opponent's beliefs or to emphasize the agenda of a political player.

Developed countries have searched for ways to foster the involvement of diverse stakeholders in evidence-informed public policy design for many years, with varying approaches.[44] As an example, the Science & Technology Policy Fellowship (STPF) organized by the American Association for the Advancement of Science (AAAS) in the U.S. provides training to hundreds of scientists every year.[45] This has been followed by initiatives in Australia, Canada, India, Israel, and the UK. Moreover, similar initiatives to build bridges between science and policy have emerged in Latin American countries,[46,47] such as through the Inter-American Institute for Global Change Research (IAI), where nations of the American continent participate in a Science, Technology, Policy (STeP) Fellowship Program.[48] This kind of program has taken on an increasingly vital role in both developed and developing countries. However, the efforts need to be institutionalized over time and evolve.

Most of these programs and initiatives aim to develop relations between science and policy in a real environment. This interaction allows scientists to learn first-hand the need to bring scientific evidence closer to inform decision-making (i.e., *science for policy*) while at the same time allowing the scientists to understand how essential it is to have good policies that promote adequate conditions for scientific development (i.e., *policy for science*).[23,49] Similar interfaces can also be identified between science and diplomacy (i.e., *science diplomacy*).[24,50] Collaboration between science and policy stakeholders is built upon meaningful relationships and often requires that all parties develop new communication skills.[51] Initiating successful relationships with other members of the scientific community, associations or academies, universities, businesses, legislators, and civil society organizations, among others, is a challenging task that also requires trust to be sustainable.

To bridge the gap between scientists and policy-makers and build trust and relations to turn evidence-informed policy-making into practice, the position of a scientist within the government is vital. Wilsdon identified four structures as the most commonly used across different countries: (i) advisory councils (e.g., Japan's Council for Science, Technology and Innovation (CSTI), the UK's Council on Science and Technology (CST), and the U.S. President's Council of Advisors on Science and Technology (PCAST)); (ii) advisory committees; (iii) national academies, learned societies and networks (e.g., the International Science Council (ISC)); and (iv) Chief Scientific Advisors.[52] Only a few nations have the position of a Chief Scientific Advisor, such as Australia, Canada, India, Ireland, Malaysia, New Zealand, the UK, and the U.S.[52] The European Union (EU) has the Scientific Advice for Policy by European Academies (SAPEA) and a group of chief scientific advisors that form the Scientific Advice Mechanism (SAM).[19] Moreover, the Joint Research Centre (JRC, detailed in Info Box 2)[53] is an example of an institutionalized science for policy program with independent scientific advice. The vast majority of both developed and developing nations have commissions for science and technology in their legislative branches, including offices that work to provide scientific and technological information and advice.[54]

Info Box 2. The Joint Research Centre (JRC), a Directorate-General of the European Commission (EC), is an example of an institutionalized science for policy program. The science and knowledge service provides independent scientific advice and technical support to the EU.[53] The JRC's headquarters are in Brussels, Belgium. In addition, several offices and laboratories are spread across Europe, working on critical issues, including energy, transport, environment, resource scarcity, climate change, sustainability, innovation, food, nutrition, and health. The JRC aims to anticipate emerging issues so that policy-makers can respond to significant challenges as they face them. The JRC has several specialist laboratories and facilities to conduct scientific research and collaborates with EU member states, the scientific community, and partners worldwide. In 2020, the JRC published a "Science for Policy Handbook" that provides an overview of the science-policy environment.[23]

The models of science advice vary across countries; however, all have similar objectives influenced by historical, cultural, institutional, and political-economic contexts.[13] Important distinctions between advisory offices and agencies, committees, boards, and councils lie in their involvement with government. Science offices and agencies are typically closely associated with the government, with regulatory agencies being essential to government operations. In contrast, scientific advisory committees and boards are composed of diverse groups of experts in several fields, who are typically independent, providing advice and direction. Councils are very similar to advisory committees but include external stakeholders and partners, such as citizens, beneficiaries, and civil society groups. The benefits of both include members typically serving for short terms, with membership changing to reflect the needs of the committee or council based on the required knowledge and diversity. Furthermore, councils provide deliberation platforms that facilitate bridging disciplines and sectors, emphasizing active discussions and debates to integrate both scientific and non-scientific knowledge for alternative problem-framing and solutions.[55] Academies are another stakeholder that play a significant role in evidence synthesis in science advice; however, a purely academic model lacks brokering mechanisms, which are crucial for meeting the needs and timeframe of policy-makers.[13]

The advisory offices and agencies, committees, boards, and councils have several benefits that surpass those of an individual Chief Scientific Advisor who disproportionately

influences policy decisions. This was a major reason for the removal of the role of the Chief Scientific Advisor in the EU in favor of the Group of Chief Scientific Advisors, who act independently in the public's interest.[56] While some countries still appoint a Chief Scientific Advisor, in New Zealand and the UK, for example, the Chief Scientific Advisor is supported by a committee of science advisors or chief scientists in individual committees that function as a *de facto* advisory committee. This approach ensures that a diverse set of scientists, all experts in their fields of study, are included. *Science for policy* provides scientific evidence to inform public policy-making. Thus, a broad, pluralistic skillset and approach are essential.[13]

The complexity and differences between legislative bodies have been recognized as one of the main challenges to understanding science advisory structures.[57] Intergovernmental structures, such as the Intergovernmental Panel on Climate Change (IPCC) or Inter-Parliamentary Union (IPU), were designed and established to provide regular scientific assessments and platforms for exchange on pressing global issues. However, given several challenges, such as global versus local perspectives, scientific disinterestedness versus policy relevance, and consensus versus plurality, accompanied by a lack of engagement by policy-makers, agreements were difficult to achieve and implement.[58,59] In other instances, the United Nations (UN) has been working on raising attention to specific topics, such as the UN Convention to Combat Desertification Science-Policy Interface.[60] Complexities of policy advice structures at national levels are further reinforced when global challenges need to be tackled, as the case for the IPCC shows. The challenges of the 21st century require including broader scientific knowledge and diverse perspectives across generations, while structuring global policy-making.

Barriers to Engagement

Engaging early-career scientists in policy-making offers transdisciplinary benefits for both scientists and society, such as the development of soft skills, decision-making abilities, and social capital, as well as the betterment of prevailing systems in terms of transparency and accountability. Furthermore, higher involvement induces a sense of ownership among individuals, which is a key factor for the success of policies.[61] However, there are several challenges scientists, especially early-career scientists, face if they are interested in participating in the policy-making process. These include social, cultural, political, institutional, and personal barriers, and the complexity of political decision-making processes (Table 1).[62]

Social barriers often result from predefined roles in society, unbalanced distribution of power, hierarchical structures, and other factors influenced by social norms, which result in the marginalization of early-career scientists in policy-making.[62] For example, policy or public engagement is often not considered integral to a scientist's profession. However, there is substantial agreement on science being a vehicle of social inclusion in society.[63] This contradiction must be resolved to include scientific advice. These social norms are closely linked to cultural values.[64] Values and traditions in a community can hinder the participation of early-career scientists in policy-making. Lack of trust and perceived readiness to engage with politics and policy paradigms often prevent early-career scientists from being recognized as stakeholders in decision-making processes.[65,66] These barriers restrict early-career scientists' participation in the science-policy interface, which can also be hindered by political obstacles, such as issues related to access, as well as opportunities and support by political authorities.[62] Furthermore, the national political situation can be a barrier to engagement, depending on how open governmental bodies are to receiving scientific advice.[63]

Excessive formalities and complexities in decision-making structures and processes, lack of training in science communication and development of the skills for better engagement with policy-makers and stakeholders, and a skeptical environment are additional institutional barriers.[63,65] Training programs in science policy and diplomacy are often focused on the national and subnational level and lack international perspectives. Moreover, most training programs are located in developed countries. Even if it is possible in middle-income countries to initiate training programs for scientific advice with individual efforts, the described barriers and the nature of changing governments and institutional leadership endanger the long-term continuation of such programs.[67] A lack of mentorship of early-career scientists in communicating with policy-makers also means that there are no opportunities for development. However, mentorship programs can facilitate a cultural shift in science and academia. Early-career scientists are often supervised and mentored by more senior scientists who are key in supporting them to participate in such directions. Differences between the goals of scientists and policy-makers further pose a barrier to engagement.[68] Taking time off from studies and research to engage with policy-makers is often neither acknowledged nor considered during job promotions, which poses an additional barrier to those scientists in dependent positions with lower job security.

In addition to social, cultural, political, and institutional challenges, personal perceptions can be a barrier, such as a lack of interest in policy-making due to missing role models, an underappreciation of one's competencies, and wrong views about the complexities of getting involved. Those scientists successful in policy-making are hidden, their stories and career paths are often not known or, if known, they are not celebrated. Their day-to-day work and life are not understood to the level that other career paths in science are known or appreciated. Furthermore, professional instability, lack of funding, time, and institutional support to conduct primary and transdisciplinary research can be challenging.[63] It is the responsibility of governments and society as a whole to ensure that science and evidence-informed policy-making are well-funded, which is also important for a country's competitiveness for new technologies, and response to crises.

Table 1: Summary of barriers to early-career scientists' engagement in policy-making and potential mitigation actions to be addressed by senior scientists, academies, and other stakeholders in the science-policy interface.

Barriers	Potential Actions
Social and cultural	
• Marginalization of early-career scientists • Hierarchical structures • Lack of trust and recognizing early-career scientists as stakeholders	• Recognize early-career scientists as stakeholders • Provide equal responsibilities to early-career scientists in committees and boards (e.g., voting rights)
Political	
• Lack of access, opportunities, and support • Negative political environment (not open to scientific advice) • Limited two-way communication between science and policy	• Support mechanisms for scientific advice • Create platforms for exchange with policy-makers • Strengthen interface bodies for an effective two-way communication (for instance via Chief Scientific Advisors)
Institutional	
• Lack of training in science communication • Lack of mentorship • Excessive formalities in decision-making processes • Differences between the goals of scientists and policy-makers • Assessments and promotion criteria; lack of visible professional reward (compared to publications, conference presentations)	• Train early-career scientists in science communication with policy-makers and vice versa • Mentor early-career scientists • Communicate decision-making engagement channels • Recognize, value and encourage participation in science-policy interface initiatives in the promotion criteria • Challenge academic structures to recognize societal impact
Personal	
• Lack of role models of early-career scientists in policy-making • Underappreciation of scientific competencies and lack of confidence in own expertise • Perceptions about the complexities of getting involved • Professional instability and lack of funding and time	• Teach and promote role models in science-policy advice in the same way as careers in academia or industry • Establish programs for fostering the involvement of scientists • Train early-career scientists in science communication • Provide funding mechanisms for transdisciplinary research
Complexity of political decision-making	
• Complex coordination across sectors and actors to build consensus for action among diverse interests, and inform strategy setting • Complex implementation and cooperation between countries and regions; timing and stringency of governance	• Provide training and streamline processes so that new stakeholders can meaningfully contribute to policy-making • Emphasis on capacity building, finance, governance, and technology transfer

To be a professional science advisor, one must commit a considerable amount of time, ideally as a full-time job. A significant dedication to policy work is often only possible when a senior scientist is appointed to an official science advisor role while the academic work is paused. Science advice could nonetheless co-exist with a job in academia or industry, in addition to career paths with full-time dedication. Moreover, concerns about the politicization of science,[42,69] and an inability to differentiate between being a knowledge broker and an advocate can negatively influence early-career scientists' engagement with policy-makers.[63,68] Scientific academies and society are crucial in addressing these challenges and contributing to the science-policy interface.

The challenges of recognizing early-career scientists in national and global policy-making constitute a barrier to their involvement while leading to a lack of diversity due to unequal access for historically marginalized communities.[70] In cases where early-career scientists are included in scientific advisory bodies, the lack of inclusivity may limit their participation and voice in decision-making. Enhancing diversity can lead to advantages for both research and society.[71] Inclusive, affirmative actions can guarantee the plurality and diversity of actors,[67,72] which also applies to early-career scientists. Diverse participation in policy-making is crucial for developing scientific and technological policies that can address current global challenges and promote sustainable development.[73,74]

The Role of Scientific Academies and Societies

Merit-based learned academies and societies (collectively referred to as "academies" hereafter) have a long history, which points to their value and impact on greater society.[75] Academies provide a space for scientists at all stages of their careers to build collaborative networks, attend and contribute to conferences, and engage in professional development.[76] Furthermore, academies function as a formal platform for scientists to get involved in policy discussions with funders and governmental bodies, and to interact with other researchers across differing career stages, institutions, and countries to progress their discipline. Despite these benefits, many well-established academies suffer from aging, declining membership, and diminished influence in societal affairs.[77,78] This is somewhat unsurprising, as the present-day knowledge landscape is filled with a diverse set of new actors, modes of idea exchange, and communication that academies have struggled to keep up with.[78] With this comes general skepticism, notably from

early- to mid-career scientists, of the role of traditional academies and whether their current members (mostly senior academics) are best suited to address emerging social challenges.[78] The question arises: how can emerging scientists engage with or transform academy models to ensure that these institutions respond to and support new, shifting societal demands?[79]

Currently, there are many ways in which emerging scientists can engage in academy activities that work toward addressing complex challenges, which serve as the primary point of entry for any aspiring academy member. These include attending and contributing to board or other leadership meetings, serving and volunteering on society committees or working groups, advancing policy papers and frameworks for submissions to calls for feedback on a given policy or issue, and organizing workshops or programs around a given topic. Funding, in the form of small grants, is often available to cover the costs of travel and meeting organization. There is an abundance of programs and resources across the globe from different academies.[80–88] It is important to point out, however, that although these serve as a means of accessing scientific academies and societies, the benefits to most academies of an emerging scientist's contribution outweigh the benefits received by the individual—especially if that individual does not have voting membership status.[89] If emerging scientists are to engage in international policy-making via academies, it is our opinion that academies should increase their efforts on transforming the classic academy model into one that is fit-for-purpose for the 21st century, as suggested in the InterAcademy Partnership Report on "Improving Scientific Input to Global Policymaking with a Focus on the UN Sustainable Development Goals" (Table 2).[90–92] An illustrative example of such efforts is the Academy of Science of South Africa (ASSAf, detailed in Info Box 3), which is committed to diversity and includes early-career scientists while providing national policy advisory.[93] Another example is the ISC that is offering free affiliate membership to young scientific groups to engage them and encourage international, intergenerational, and interdisciplinary collaboration and dialogue.[94]

Info Box 3. The Academy of Science of South Africa (ASSAf), established in 1996, serves as the scientific advisory body in support of policy development in South Africa.[93] Its activities include the publication of consensus study reports and policymakers' booklets on key topics and commentaries on national policies. ASSAf is also committed to including women and early-career scientists in its activities. It provides secretariat support to the South African Young Academy of Sciences (SAYAS), established in 2011, which is affiliated with the Global Young Academy (GYA). SAYAS serves as a platform for early-career scientists in South Africa to influence policy decisions and hosts regular webinars on topics such as policy advocacy and diplomacy. In addition, members of SAYAS also serve on the ASSAf's Science Advisory Group on Emergencies (SAGE).

Transforming the academy model would help infuse all areas of science with diverse ideas and engage the next generation of science leaders. Any opposition to change hinders the evolution of classic academies. Senior scientists

Table 2: Transforming the models of academies to ensure the engagement of emerging scientists. This table is adapted from the InterAcademy Partnership's 2019 Report on "Improving Scientific Input to Global Policymaking with a Focus on the UN Sustainable Development Goals".[90] The "classic" model represents traditional academies with standard procedures, whereas the "adapted" and "transformed fit-for-purpose" models are two models with increasing degrees of deviation from the "classic" one. Academies may include elements of multiple models in their practices.

Model	Classic	Adapted	Transformed Fit-for-Purpose
Purpose	Promotion of the fields that the academies represent and honoring of the most successful practitioners	Evidenced-informed decision-making and the promotion of knowledge	Most widely trusted knowledge informs decision-making
Membership	Nominated and evaluated by existing members based on exceptional merit	Nominated by anyone (including themselves), transparent selection process based on merit in both research and service; deliberate attention to diversity and interdisciplinarity	Inclusion based on defined criteria (e.g., PhD, science and/or policy related metrics; considering biases when identifying the criteria)[95]
Tenure	Lifetime with no consequence for inactivity in research or service	In an early-career academy, 4 to 5 years. In a senior academy, voting membership for limited time; thereafter honorific unless elected to a formal position	If they remain active in research or service
Funding	Bequests, endowments, donations, member subscriptions, partial state subsidy	State subsidy for core operations, contracts for studies requested for the academy, endowments for special projects	Entirely out of public funds or based on contracts
Disciplines	Separate academies for sciences, humanities, engineering, and health	Unified or federated academies for all endeavors with a rationalist epistemology	Unified academy for all knowledge systems, including indigenous knowledge
Geographic Scope	National, sometimes subnational, and a few regional or global	National, but with voluntary regional or global cooperation/function	Globally coordinated, but locally organized

that are active in existing academies should embrace and support efforts by early-career scientists to transform the academy model. These efforts could provide a unique perspective on emerging issues that impact future generations of science practitioners, improve academies' outreach activities, increase organizational productivity, and create new content, programming, and mechanisms for interacting with greater society. Fostering interactions and relationships between senior and junior scientists will also help identify and recruit present and future leaders.

In addition to making academies more dynamic in their structure, it is important to achieve greater diversity at all levels. Academies and scientific societies presently tend to have a higher representation and engagement of scientists working in academia compared to those scientists working in other fields. While governments would benefit from diverse perspectives from scientists of various backgrounds, it would also ensure a better representation of the general population. For example, professors often come from socio-economically privileged backgrounds,[96] whereas several issues currently pressing society, such as climate change, will disproportionately affect low-income populations.[97] Generally, the lack of diversity needs to be broadly recognized, and the inclusion and support of historically marginalized groups must be ensured in the development of academies and scientific societies globally.

Transforming the academy model is a significant undertaking. To this end, Boudreau et al. proposed simple, concrete steps for members and emerging scientists:[89]

- ***Build a talent pipeline*** accessible to all emerging scientists and make more efforts to include emerging scientists on existing committees to provide them with a seat at the table. Add specific emerging scientists as board members or to other leadership positions as appropriate.
- ***Support and mentor*** emerging scientists that adopt leadership positions. Motivated academy members and staff are valuable resources. Mentorship should be explicitly provided for the position so the emerging scientist can master the required skills. Stagger these positions (e.g., three-year term with one-year overlap) to create a perpetual peer mentorship structure.[18,98,99]
- ***Set equal responsibilities*** to give emerging scientists the same responsibilities as other board members or leaders.
- ***Value emerging scientists' voices*** by providing a safe and inclusive space and orientation.[70]
- ***Accommodate emerging scientists' needs*** and be aware of the conditions at different life stages.
- ***Request constant feedback*** to learn how the experience benefits emerging scientists, what barriers persist, and what ideas need further attention.

These steps could help transform the academy model to meet today's modern challenges and ensure sustainable development.

Scientific Early-Career Networks

In addition to scientific academies that serve as one source of science advice for governments,[13] early-career networks can substantially contribute to the scientific advisory ecosystem (Figure 2). In particular, scientific networks gather early-career professionals across disciplines internationally, which can provide an intermediary body for coordinating the process of identifying and connecting relevant science advisors. For instance, the European Young Chemists' Network (EYCN) is the young division of the European Chemical Society (EuChemS) connecting early-career chemists across Europe.[81] They have established a platform for science (for) policy with the support of EuChemS, resulting in collaboration with various academic, industrial, and governmental bodies aiming to involve early-career chemists in the policy decision-making process.[19] This has involved representatives of the EC and the contribution to activities revolving around the European Green Deal.[19] For instance, EYCN members organized panel discussions with policy-makers on relevant topics such as "The role of early-career professionals in driving sustainable innovation" at the European Parliament on the occasion of the European Innovation Summit in 2020.[100] With chemistry playing a critical role in a range of pressing global issues, from the climate emergency to healthcare crises, engaging early-career chemists in the science-policy dialogue can contribute to addressing some of these contemporary challenges. With that in mind, as a result of EYCN's science (for) policy efforts, they have been involved as stakeholders in the EC's recent "Safe and sustainable by design" strategy,[101] which recommends safety and sustainability regulations for chemicals in Europe.

Following these examples, the International Younger Chemists Network (IYCN), an associated organization of the International Union of Pure and Applied Chemistry (IUPAC), has recently established a Science for Policy Committee to engage early-career chemists in science for

Figure 2. Overview of approaches by academies, scientific societies and networks to engage early-career scientists in policy-making.

policy globally.[102,103] This provides an opportunity to gather an international community of early-career chemists invested in science policy advice. In this regard, the IYCN organized a symposium on the "UN Sustainable Development Goals (UN SDGs) for the Benefit of Society" at the IUPAC World Chemistry Congress in 2021, focusing on the contributions of chemistry to reach the UN SDGs by 2030.[104] Moreover, the IYCN is partnering with IUPAC in a joint project entitled "Global Conversation on Sustainability" aiming to raise awareness for the importance of implementing sustainable practices globally, launch synergies across countries and continents, and effectively take actions toward sustainability.[105,106] The IYCN partners with local and international organizations to reach its goals, such as scientific societies, institutions, and networks that are focused on a relevant topic, such as the International Sustainable Chemistry Collaborative Centre (ISC3) or Beyond Benign.[107] Building trusted relationships and reaching out to policy-makers can be facilitated through joining international networks,[108–110] which are becoming increasingly relevant given the problems society and science face across borders.[111]

Similarly, the National Science Policy Network (NSPN, detailed in Info Box 4) has catalyzed the engagement of early-career scientists and engineers in policy-making in the United States.[112] In addition to fostering a community of early-career professionals interested in scientific advisory, the NSPN provides training opportunities while nurturing science advocacy. This has involved exchange programs, workshops, and scholarships for science for policy events. The financial support in the form of the NSPN professional development fund supports advancing science policy, advocacy, communication, and diplomacy.[113]

Info Box 4. The National Science Policy Network (NSPN) offers unique funding opportunities for its student and early-career members and affiliate chapters to support professional development and collaborative advocacy.[112] As of 2022, these opportunities included the Chapter Development Fund to develop new or grow existing local chapters of early-career members; the Chapter Diverse, Inclusive Collaborative Expansion grant to support initiatives in partnership with historically marginalized communities; and the Professional Development Fund for individuals to pursue networking, leadership, and communication skills. These mechanisms fill a critical gap for early-career scientists interested in science policy, where a lack of resources can pose a barrier to engagement.

On a broader interdisciplinary level, the Young Academy of Europe (YAE) established the Young Academies Science Advice Structure (YASAS) to join the SAPEA project and give early- and mid-career scientists a voice in European science policy advice.[114,115] Similarly, the GYA is an international society for members under 40 years of age aiming to give early-career scientists worldwide a voice. The GYA was founded in Berlin, Germany, in 2010, and there are presently 54 young academies all over the world (as of November 2022), with several initiatives for launching such networks in progress. GYA members foster international, intergenerational, and interdisciplinary collaboration and dialogue and are active in science advice.[82] Finally, the International Network for Science Governmental Advice (INGSA, detailed in Info Box 5) provides an international collaborative forum for policy-makers, academies, scientific societies, practitioners, and researchers to share experiences and build capacities to use science in informing governmental policy.[77] Such international initiatives and schemes are essential to enhance scientific advisory mechanisms (inter)nationally by training the next generation of leaders and engaging them early in their careers.

Info Box 5. The International Network for Science Governmental Advice (INGSA) is affiliated with the ISC and was founded in 2014.[77] It has chapters in Africa, Latin America, the Caribbean, and Asia. There are plans to expand into Europe and the Middle East. The main objective is to improve the global science-policy interface through conferences, workshops, and other tools and provide guidance to increase the potential for evidence-informed policy formation at the subnational, national, and even transnational levels. INGSA forms a network between policy stakeholders and builds capacity for early-career and experienced scientists by bringing together diverse global science advisory organizations and national systems.

It is critical to support scientific early-career networks and organizations with international reach that can engage scientific advisors. This could also involve the creation of new international bodies, such as non-governmental organizations or programs, with the capacity to engage early-career scientists and provide resources to promote scientific advice. Such an international investment could form the basis for a *global scientific advisory mechanism*, shaping the process in all dimensions of both scientific evidence synthesis and knowledge transfer globally. Toward this goal, building capacity through training the new generation of early-career scientists and policy advisors is critical and requires international attention.

Training Scientists for Policy Advice

To build capacity for science policy and diplomacy in the scientific community, there is a need to develop programs to empower scientists, particularly during the early stages of their academic training.[116] Previous studies identified that traditional scientific training leaves critical gaps in science policy skills, including unfamiliarity with government operations and insufficient communication experience.[117] While the value of scientists trained in diplomacy (and vice versa) is widely recognized, higher education institutions are not prepared for such opportunities.[118]

For scientists to get involved in policy-making, they must learn to speak two languages, one of science and one of politics. Scientists need to understand the policy-making structures in their community, their roles in formulating policy, and their associated actors. There remains relatively little formal study and documentation of how policy-makers and scientists work together globally, and further work is truly needed.[51] While more training programs are required, several initiatives can serve as models to facilitate the training of scientists in the policy-making process. One of the most well-known examples of this is the STPF hosted by the AAAS (detailed in Info Box 6), which has placed scientists and engineers in year-long assignments in the federal, legislative, and judicial branches in the U.S. for many years.[45] Various professional scientific organizations, including the American Chemical Society (ACS), sponsor fellows through this program. More broadly, some science policy-focused organizations offer short-term training experiences in science policy and diplomacy targeted at early-career researchers, including those who may still be students. Representative examples of other fellowships and short-term training experiences are summarized in Table 3.

Info Box 6. The AAAS Science & Technology Policy Fellowship (STPF) program places STEM (Science, Technology, Engineering, and Mathematics) professionals with graduate-level academic training, many of whom are early-career scientists, directly in offices as

Table 3: Training opportunities for early-career scientists in science for policy and diplomacy. This list is not meant to be exhaustive but represents some options available to early-career scientists worldwide.

Program	Description
AAAS Catalyzing Advocacy in Science and Engineering (CASE) Workshop	Annual four-day, entry-level program to educate U.S. STEM students about the role of science in policy-making and the federal policy-making process, and to empower them to become a voice for basic research throughout their careers.[120]
AAAS-TWAS (The World Academy of Sciences for the advancement of science in developing countries) Course on Science Diplomacy	Annual week-long training program bringing together scientists, policy-makers, and diplomats to explore key contemporary international policy issues related to science, technology, environment, and health, and build a skillset to allow for careers at the intersection of science and diplomacy.[121]
Australian Science Policy Fellowship Program	Full-time fellowship for early- and mid-career scientists and engineers to work for up to 12 months as a policy officer at participating Australian government host departments. The goal is to develop skilled policy practitioners for bringing scientific expertise to policy-making.[122]
Christine Mirzayan Science & Technology Policy Graduate Fellowship	Full-time fellowship for early-career scientists and engineers to spend 12 weeks at the National Academies of Sciences, Engineering, and Medicine in Washington, D.C., USA, learning about science and technology policy and the role that scientists and engineers play in advising the nation.[123]
JRC Collaborative Doctoral Partnerships	Allows selected doctoral students the opportunity to conduct part of their doctoral studies at the Joint Research Commission in Europe, with a specific focus on topics at the science-policy interface.[124]
Geneva Science and Diplomacy Anticipator (GESDA) Science Diplomacy Week	Week-long program for mid-career science and diplomacy professionals, including an introduction to the science diplomacy ecosystem and an open forum for exchange among the expert public, early-career professionals, and students interested in the interface between science and diplomacy.[125]
IAI STeP Fellowship Program	Places early-career STEM fellows in host government or private organizations across Latin America and the Caribbean to engage first-hand with policy- and decision-makers and facilitate the uptake of scientific knowledge into policy processes.[48]
Meridian-NSPN Diplomatic Skills Training Course	Short-term, intensive online course for early-career U.S. scientists that teaches soft skills such as communication, crisis management, and cross-cultural competencies required for a diplomacy career transition.[126]
NSPN Science Diplomacy Fellowship	Six-month program that partners groups of early-career scientists with science diplomacy organizations, including consulates and embassies. Fellows engage in cross-cultural, team-based projects that contribute to the work of the sponsoring organization and increase collaboration opportunities for science diplomats in the field.[127]
NSPN Science Policy Scholars in Residence Program	Six-week bootcamp for early-career scientists to develop and practice policy-relevant skills, followed by a six-month internship where participants work closely with an external organization in science policy to develop a project that aligns with their professional development goals.[128]
São Paulo Innovation and Science Diplomacy School (InnSciD SP)	A week-long, online course providing training to scientists, diplomats, and representatives of the private sector from all over the world on the rich and multidisciplinary intersection between science, technology, innovation, and foreign policy.[129]

staffers across the executive, legislative, and judicial branches of the U.S. government for an immersive, year-long experience.[45] The program started in 1973 and provides fellows with direct experience in policy-making and implementation while benefiting the U.S. government with their technical expertise on topics ranging from energy diplomacy to scientific publishing. The program has successfully developed science policy leaders across government, academia, industry, and the non-profit sector. Approximately half of the alumni decide to stay in the policy arena. In a 2020 survey conducted by the STPF program,[119] including 1200 alumni and 230 government mentors, 89 % of the fellows approved of the program. Moreover, 84 % of the fellows and 97 % of the mentors believed that fellows had the opportunity to use their knowledge and expertise to make meaningful contributions to the work of the host office. Self-reported policy know-how and skills increased significantly across metrics including workings of government, collaborative, and science-policy integration skills. Being a fellow overwhelmingly impacted subsequent professional activities, with 49 % of survey respondents taking a government position immediately after their fellowship.

While these programs are excellent resources, they remain inaccessible for many early-career scientists, with limited spots, restrictions based on citizenship and academic degree, and commonly requiring long-term, full-time commitment. A few academic institutions offer structured coursework opportunities for STEM students interested in policy.[130] However, most academic institutions, where most early-career scientists are based, rarely offer formal opportunities or incentives to explore the area of science for policy and diplomacy.[111] Furthermore, even in cases where these resources exist, they are often only modestly funded, U.S.-centric, and lack real-world experiential training.[131] Overcoming these challenges and bringing such training programs into mainstream practice will likely require additional pressure and resources from large scientific organizations and funding agencies. For this purpose, increasing awareness about the importance and impact of scientific advice could facilitate the engagement and development of appropriate programs for scientists to contribute to policy advice. Early-career scientists interested in the science-policy interface may proactively build a network and seek entry and training opportunities.[109]

Summary and Outlook

In summary, scientists are critical to enabling evidence-informed policy-making. However, this process and scientific involvement remain challenging nationally and internationally due to the complexity of scientific advisory mechanisms across countries and the lack of clarity surrounding critical stakeholders. Moreover, there are still societal, political, and institutional barriers to involvement in the scientific advisory process, particularly related to the appropriate training required for scientists to contribute to policy-making. To address these pressing issues, scientific academies, societies and networks play an important role in raising awareness and transparency about policy advice mechanisms, providing training programs and increasing visibility and mentorship (Figure 3). While such training will equip early-career scientists with expertise and communication skills to interact with policy-makers and society as a whole, host institutions will also benefit from such programs. As scientists become proficient in articulating the importance of their scientific work, these skills will be beneficial when seeking research funding and they will become visible ambassadors for their institutions.

Early-career scientists have several opportunities to get involved and contribute to policy-making. They can join or establish national young science academies, such as through collaboration with the YAE or the GYA and its science advisory activities, which provide opportunities for increasing awareness and experience. Furthermore, scientific networks, institutions, and initiatives, such as NSPN, INGSA, AAAS, SAPEA, and JRC, offer training programs for early-career scientists in policy-making. To this end, chemistry-related fields provide important resources for tackling contemporary challenges, including sustainable development. Networks, such as the EYCN, the IYCN, or the NSPN, support early-career chemists and scientists in getting involved in policy-making.

In academic settings, it is essential to recognize the engagement of scientists with policy-making in assessment and promotion criteria. Most universities do not consider it at this time, resulting in a lack of motivation and time allocation for these activities, especially compared to other requirements such as publishing, patenting, mentorship, and teaching. More formally incentivizing engagement in the science-policy interface will likely increase participation, particularly among early-career scientists. For example, students will benefit from the design of courses on science for policy and diplomacy at the university, creating a new generation of scientists with basic knowledge of science-

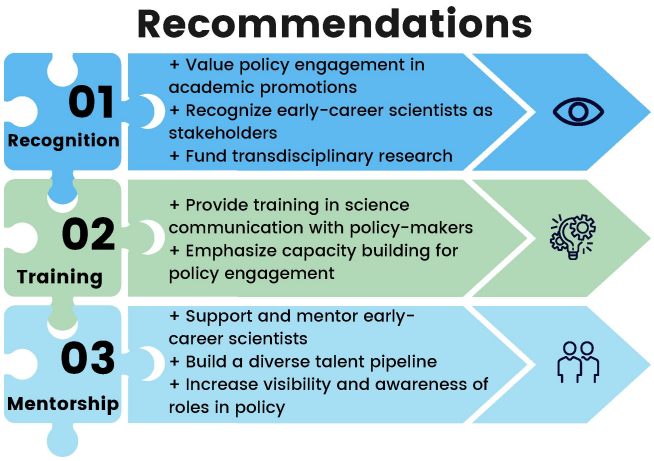

Figure 3. Recommendations for facilitating the engagement of early-career scientists in policy-making.

policy interfaces. Such systems will also help to create a critical mass of scientists who consider engagement with society not as an exception but as a normal activity.

New programs encouraging scientists and engineers to engage in policy-making should take advantage of the existing scientific infrastructure. For example, many STEM PhD students are funded through federal grants and participate in specific coursework, such as ethics training, as a requirement of this funding.[132] Similar training could be developed to help researchers to understand the policy implications of their own research and how their research can be used to inform public policy better. Furthermore, universities and government funding agencies frequently require applicants to provide statements of "broader societal impact", with the expectation that scientists leverage tools of scientific communication to engage with the public. However, scientists are rarely trained to present their research to policy-makers, and institutions and funding agencies do not sufficiently incentivize transdisciplinary practices. Those institutions and academies leading successful initiatives can serve as a model to follow. Providing guidance to funding recipients that explicitly focuses on engaging with policy-makers as a mechanism to fulfill broader impact requirements could be a way to incentivize and reward these types of activities. These and other practices would enable academic institutions to increase the capacity of early-career scientists to leverage their scientific expertise to advance science policy and diplomacy globally.

Abbreviations

AAAS, American Association for the Advancement of Science; ACS, American Chemical Society; ASSAf, Academy of Science of South Africa; CASE, Catalyzing Advocacy in Science and Engineering; CST, UK's Council on Science and Technology; CSTI, Japan's Council for Science, Technology and Innovation; EC, European Commission; EuChemS, European Chemical Society; EU, European Union; EYCN, European Young Chemists' Network; GESDA, Geneva Science and Diplomacy Anticipator; GYA, Global Young Academy; IAI, Inter-American Institute; INGSA, International Network for Science Governmental Advice; InnSciD SP, São Paulo Innovation and Science Diplomacy School; IPCC, Intergovernmental Panel on Climate Change; IPU, Inter-Parliamentary Union; ISC, International Science Council; ISC3, International Sustainable Chemistry Collaborative Centre; IUPAC, International Union of Pure and Applied Chemistry; IYCN, International Younger Chemists Network; JRC, Joint Research Centre; LYEA, Local Youth Environment Assembly; MGYC, Major Group for Children and Youth at UNEP; NSPN, National Science Policy Network; PCAST, U.S. President's Council of Advisors on Science and Technology; SAGE, ASSAf's Science Advisory Group on Emergencies; SAM, Scientific Advice Mechanism; SAPEA, Scientific Advice for Policy by European Academies; SAYAS, South African Young Academy of Sciences; STEM, Science, Technology, Engineering, and Mathematics; STeP, Science, Technology, Policy Fellowship; STPF, Science & Technology Policy Fellowship; TWAS, The World Academy of Sciences for the advancement of science in developing countries; UN, United Nations; UNEA, United Nations Environment Assembly; UNEP, United Nations Environment Programme; UN SGSs, United Nations Sustainable Development Goals; YASAS, Young Academies Science Advice Structure; YAE, Young Academy of Europe.

Notes

We have provided a selection of institutions, organizations, instruments, programs, networks, and other bodies throughout the manuscript without the aim of having a comprehensive overview. Instead, our focus has been on those representatives recognized for early-career scientists' involvement, particularly in chemistry-related fields. Moreover, we aimed to provide representation across continents whenever possible. The info boxes provide more information about relevant institutions and programs with representation across the globe (1: global; 2: Europe; 3: South Africa; 4&6: U.S.; 5: Africa, Latin America, Caribbean, and Asia). The choice of highlighted organizations also reflects the background and experiences of the authors.

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Conflict of Interest

T.J., B.L.D., L.R., J.V.M., and J.B. are committee or board members of the IYCN, whereas T.J., J.V.M., and J.B. have also been team or board members of the EYCN. T.J. is a member of the ISC3 Advisory Board. In addition, J.V.M. is a member of the GYA, together with A.C.H.-M., who is also a committee member of INGSA Latam, whereas C.T.J. is an active member of the NSPN and an AAAS STPF fellow. L.R. has been a Youth Representative for the Chemicals and Waste Platform of UNEP-MGCY at UNEA5.2. Several authors participated in some of the events that are referred to as examples, such as the EC's Research & Innovation Days (J.V.M.), and the European Innovation Summit (J.V.M.). The Global Conversation on

Sustainability is being organized by T.J. and J.B., and J.V.M. has collaborated with GESDA and national young academies.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Disclaimer

The opinions expressed in this publication are the view of the author(s) and do not necessarily reflect the opinions or views of *Angewandte Chemie International Edition/Angewandte Chemie*, the Publisher, the GDCh, or the affiliated editors.

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Viewpoint Article

Early-Career Scientists

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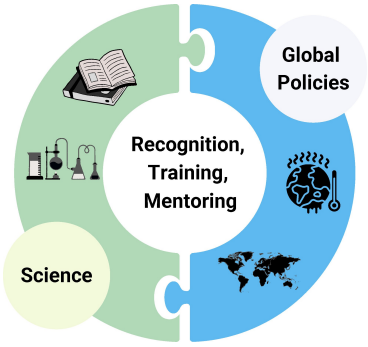
Engaging Early-Career Scientists in Global Policy-Making



Societal, political, and institutional barriers impede early-career scientists' engagement in evidence-informed policy-making to address societal challenges. Better training, recognition, and stakeholder reforms could raise awareness and involvement of scientists across disciplines in the policy-making process.