Chief Science Advisor's Youth Council
Conseil Jeunesse de la Conseillère scientifique en chef

Our Vision for Science:

Perspectives from the Chief Science Advisor of Canada's Youth Council

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LAND ACKNOWLEDGEMENT

To begin, we acknowledge that the land we are living on is the traditional territory of many different Indigenous nations. We ask that each of you take a moment to learn about and reflect upon the Indigenous people whose lands you are currently on. In the context of this report, we also invite you to reflect on how we can collectively support and amplify the voices and efforts of Indigenous scientists and researchers, and take tangible steps to address historical wrongs and persistent inequities. For example, you may choose to turn to Native Land Digital[1] to learn more about the land you are currently on, or attend University of Alberta professors Dr. Kim TallBear and Dr. Jessica Kolopenuk's course Indigenous Peoples and Technoscience.[2]

ACKNOWLEDGEMENTS

Thank you to Dr. Mona Nemer for valuing youth voices, and for encouraging and supporting us to articulate our vision for science. We would also like to thank our mentors Paul Dufour (Institute for Science, Society and Policy, University of Ottawa) and Rackeb Tesfaye (McGill University), and members of the Office of the Chief Science Advisor, especially Dr. Vanessa Sung and Nahiea Zaman, for their guidance and insights on this report.

FOREWORD FROM THE CHIEF SCIENCE ADVISOR OF CANADA

Science is one of our greatest assets for tackling global challenges and building a better future, and it is essential that the voices of the next generation help shape that future. In March 2020, I was delighted to announce the inaugural Chief Science Advisor's Youth Council. This group of exceptionally bright young scientific trainees, researchers, and professionals was recruited from across the country, each bringing their own unique expertise, knowledge, ideas, and lived experiences. They are tasked with providing me and my office with input on scientific issues from the youth perspective, as well as bring to our attention issues that are important to them as young members of Canada's scientific community.

One of the key questions I asked them was this – how do you envision the future of science and research in Canada? It is a big question, but they were up to the task.

In this report they discuss, in their own words, what they observe in the current scientific landscape and what they envision it could look like in the future. It is an ambitious report that covers a wide range of topics, but a clear theme that emerges is the desire to see the breaking down of walls in science, including between knowledge systems, between disciplines, between sectors, between career paths and between populations in society. The vignettes of personal reflections from individual Youth Council members are a particular joy to read, as they infuse the report with the hope and inspiration that emanate from young people who are motivated to positively impact the world.

In our highly interconnected world, the call to work closer together and remove barriers in science is a wise one. I urge the readers to consider seriously, as I do, the suggested actions in this report that aim to build a scientific enterprise that is more inclusive, collaborative, open, interdisciplinary and reflective.

Dr. Mona Nemer
Chief Science Advisor of Canada

PREFACE

As members of the Chief Science Advisor's Youth Council,[3] we represent the voices of the next generation of scientists and researchers. Our council is made up of members from a diverse range of scientific fields, career stages, ages, cultural backgrounds and viewpoints. But what we have consistently agreed on as a group is that science must play a larger role as we continue to tackle and navigate major global issues, including addressing climate change, reducing social inequalities and preparing for future unknowns. The culture within science and research has often maintained an insular attitude – but the work we do does not exist in a vacuum, nor is it bias-free. Building and maintaining trust with the broader society requires work from scientists and researchers across sectors to break down silos and remove barriers that restrict who can participate in, remain in and benefit from science.

In this report, we have taken up the challenge issued by Canada's Chief Science Advisor to envision the future of science and research in Canada. We discuss, in our own words and through the lens of experiences, the challenges we have observed or faced and how we envision Canada's science and research landscape can evolve, for the sake of the next generation. It is an ambitious report that covers a wide range of topics and proposes novel ideas, but does not cover every issue that the science community in Canada is facing. Instead, we have focused on breaking down walls in science, including between disciplines, sectors, career paths and society. It is an important and urgent matter for all of us, and it is our collective future that we are seeking to improve and shape.

We steadfastly believe that science in Canada must be more inclusive, collaborative, open, interdisciplinary and reflective. We envision tomorrow's science to be open and accessible to all members of society. In this report, we begin to imagine what that looks like, and we offer calls to action to a variety of stakeholders to help realize this vision in Canada.

Calls to Action

Below, we outline actions that deserve consideration by governments and relevant stakeholders across different sectors. These calls to actions are categorized by section, not urgency.

Section 2: Directions for science and research in Canada

1. Integrate different types of knowledge creation and systems.
2. Rethink how we evaluate the impact of research, with a dedicated equity lens.
3. Implement mechanisms to de-silo disciplines.
4. Provide sustainable funding to support science and research in Canada.

Section 3: Collaborations and multidisciplinarity

1. Measure the success of relationships and collaboration between sectors, with a focus on research agency, independence, recognition, accessible funding and support.

2. Improve funding for non-academic sectors.
3. Create and sustainably fund embedded training opportunities within higher education to promote movement between disciplines and sectors.
4. Enhance the role of public–private partnerships to achieve better integration of science in public policy.
5. Create more opportunities for research exchange programs both in Canada and abroad, and increase support for existing exchange programs.

Section 4: Pathways to science

1. Review, or complement, K–12 education as an opportunity to expose children to a broad range of diverse models, and empower youth with the skills to dive into the careers of tomorrow.
2. Support and recognize K–12 teachers.
3. Multiply on-ramps to science by creating and/or supporting more informal STEM experiences.
4. Re-define "research excellence" to value excellence in all of its different shapes and forms.
5. Change the approach to reviewing "excellence" across processes, including peer review, and evaluation for hiring, promotion and tenure.
6. Rethink the federal approach to graduate-level and post-doctoral scholarships and fellowships.
7. Continue to dismantle systemic and institutional barriers which impede the entry, advancement and retention of scientists who belong to historically excluded communities.
8. Provide stable jobs for researchers in Canada by strengthening publicly funded research labs.
9. Normalize the exploration of different careers in science, and make it easier to move in, around and out of science.

Section 5: Science in society

1. When it comes to writing about science, be clear, write in plain language and incorporate core principles of inclusive science communication.
2. Implement mechanisms to ensure that the language of science is accessible, starting from when science is produced and shared.
3. Create and embed more science communication training opportunities in academic institutions, with an eye to considering different career stages and training tailored to different mediums.
4. Build on existing efforts to make public engagement in science fun and inclusive, and help bring science out to the streets.
5. Implement institutional efforts to value and incentivize participation in science communication and public engagement.
6. Protect individuals who participate in public engagement and science communication efforts from harassment.

Section 6: The next generation of science advice

1. Create and embed youth councils (or other forms of youth participation) across academic institutions and levels of government.
2. Work towards ensuring genuine inclusion of youth voices and perspectives in decision-making spaces.

1. BACKGROUND

Science[a] is a fundamental part of our lives. It is intertwined with every strand of our society, from culture to innovation, and affects our everyday lives. Today, science happens everywhere: from academic, industrial, non-profit and government institutions, to laboratories, workplaces and communities around the world. Researchers continue to build on past discoveries in every field, from the social sciences to engineering, and work towards translating research findings into action. And importantly, throughout the COVID-19 pandemic, the public has seen science and research unfold in real time. Much that was formerly considered technical jargon, such as "PCR test," is now part of our everyday language.

1.1 Who are the scientists and researchers in Canada?

People engage with science in different places, and do so at different times in their lives. From education and training, to working in a myriad of related roles across workplaces, there are a considerable number of remarkable individuals contributing to Canada's science culture.

a The CSA-YC has repeatedly explored what "science" is. A general frustration has been expressed that *science* is often associated with "hard science", such as chemistry and physics, and often excludes the social sciences and humanities. The CSA-YC would like to view science as the pursuit of knowledge and understanding, but is somewhat limited by how science is perceived by outward sources.

Traditionally, science education and training often start in classrooms in elementary, middle and high schools, leading to post-secondary education at colleges and universities. In 2019, Statistics Canada reported[4] that there were a total of 587,151 post-secondary graduates (**Table 1**). Many of these post-secondary graduates, as well as international recruits, go on to pursue graduate education and training, and provide the critical ideas, talent, and labour[5] necessary for the post-secondary research being conducted in Canada. According to the Canadian Association for Graduate Studies (2018),[6] there are over 175,000 graduate students enrolled in universities, with around 127,000 and 48,000 students pursuing master's and doctoral degrees respectively.

Table 1: Selected fields of study among 2019 post-secondary graduates (Statistics Canada).[4]

Field of study	Total (2019)
Humanities	43,932
Social and behavioural sciences and law	82,521
Physical and life sciences and technologies	35,208
Mathematics, computer and information sciences	27,327
Architecture, engineering and related technologies	76,752
Agriculture, natural resources and conservation	10,854
Health and related fields	84,822

Meet Marie-Eve Boulanger, quantum physicist

Marie-Eve Boulanger: I hold a PhD in quantum materials at the Département de Physique and Institut Quantique of Université de Sherbrooke. My research involved measuring thermal conductivity in superconductors – specifically, in high-temperature copper-oxide superconductors (cuprates).

Superconductors are materials which have zero electrical resistance. However, this unique phenomenon is only seen when the temperature is extremely low, which makes day-to-day applications harder to achieve. My goal as a physicist is to understand how electronic and non-electronic properties of superconductors react under a heat flow to understand their fundamental behaviour. By doing measurements under extreme conditions (i.e., at the lowest temperature or within strong magnetic fields), we can separate and identify the different heat carriers (e.g., carriers like electrons or phonons) to further study them under various constraints. Having this kind of knowledge is one way for us to understand how to make these superconductors at room temperature, so they can be used more generally.

What I love the most about doing research is that everyday, we are at the frontiers of new discoveries, pushing the limit of science and knowledge. We don't always know the answer, and this is where the magic happens! Understanding the fundamental key properties of new quantum materials will make quantum technologies, like quantum computers, a reality.

But while the number of PhD graduates is growing in Canada, the number of available academic positions is stagnant or declining. The Council of Canadian Academies' expert panel on the labour market transition of PhD graduates[7] stated that "[i]n 2009, there were over 10,500 assistant professors in Canada, but by 2017 this had fallen to about 8,600 as universities did not fully replenish their ranks after promoting assistant professors to associate professor positions." On top of this, non-academic sectors have not significantly increased their hiring of PhD graduates.

Of course, science and innovation in Canada is not limited to universities and academic institutions. Scientists often transition to work[8] in sectors such as health, education, engineering, biotechnology and other industries. As of 2018, Statistics Canada reported[8] that there were 13,080 personnel engaged in research and development in the federal government, 2,580 across provincial governments, 151,570 in business enterprises, 75,970 in higher education, and 1,240 in private or non-profit organizations. Ultimately, it is clear that science is an integral part of Canadian society and the economy and is made up of many connected pathways.

1.2 Beyond the lab and field: Public trust in science

Breakthroughs in fields such as genomics and quantum physics are only possible in a society which is engaged with science[9] and supports both the funding of scientific research and the next generation of scientists and workers.

Amid the pandemic, the global 2021 3M State of Science Index[10] found that, in Canada, public trust in science had increased to 93% (a 5% increase since pre-pandemic times), and that trust in scientists had also increased by 5% to 90%. Similarly, a 2021 survey[11] commissioned by the Canada Foundation for Innovation, in partnership with ACFAS, found that a majority of 1,500 young people (aged 18–24)[11] in Canada held opinions consistent with science, such as agreeing that COVID-19 vaccines are safe, and that it is critical for politicians and governments to rely on science when making policy decisions.

But there are worrying signs too. For example, in the 2021 3M State of Science Index,[10] only 48% believe that this increased appreciation for science will continue once the pandemic is over (with 35% uncertain), and 85% of respondents in Canada believe that more needs to be done to encourage and keep women and girls engaged in STEM education. Furthermore, the Canada Foundation for Innovation's 2021 survey[11] of 1,500 young people found that 73% follow at least one social media influencer who has expressed anti-science views, and that one in four young people may ignore science.

However, public trust in science is also a very nuanced topic.[12] Trust in science goes beyond trust in scientific theories and principles; it also includes trust in (and buy-in to) the scientists, the practitioners, the policy and politics, the history and the communication of science. As such, the opposite of trust in science is not necessarily anti-science, but often a lack of trust in scientific and/or political systems, policies and related actors. Trust can break down in many different ways, and true efforts to rebuild relationships must take into consideration the historic and ongoing experiences of any given community. Therefore, when looking at science and science culture in the future, fostering public trust must remain deliberate, intentional and at the core of all research and programming; and just as lack of trust is not the sole responsibility of scientists and science practitioners, nor is the building of public trust.

Public trust, the pandemic and the role of community fact-checkers

Chelsie Johnson: The COVID-19 pandemic has strained and tested a lot of systems and relationships, and has further exposed deep systemic issues. And while science was brought into the spotlight during the pandemic, so were the far-reaching impacts of histories of oppression and their resulting lack of trust for many communities. This became increasingly evident starting at the beginning of the pandemic in 2020, with the sheer amount of misinformation and lack of trust. Like many other health and science professionals, I recognized a growing need in my community and brought together like-minded community members to address misinformation. I created a group called the Public Health Fact Checkers[13] to provide and support accurate, relevant public health information to our communities.

Public Health Fact Checkers is a working group composed of young professionals and graduate students with specializations in public health, epidemiology, healthcare, disaster management, community engagement, crisis communications, and more. The goal of this group was to address direct questions community members have about the pandemic in an accessible, non-judgmental approach. I found that many people were inappropriately classified as "anti-science" or "COVID deniers" when in fact their worries were more about the scientific and political institutions, rather than the scientific concepts themselves.

1.3 Looking ahead: The opportunities

However important and integral science might be to Canada's culture and society, it remains true that (i) science funding in Canada is inadequate;[14] (ii) that there are several systemic and institutional barriers[15] which impede the attraction, training and retention of scientists and researchers; (iii) that limited or no access to science and its benefits excludes communities; and (iv) that the role of trust and communities in science must not be overlooked.

Without increased and stable funding for science and research, it will be difficult for Canada to keep pace with its peer nations[16] and to attract and retain the talent it needs to continue making life-saving discoveries and technological innovations, and support public engagement with science. Without free and open access[17] to science, it will remain difficult to communicate and share science broadly, and gains made in public trust in science could erode. Without inclusive and effective science communication and public engagement, significant barriers to accessing science will continue to exist for interested stakeholders, and the broader public. These challenges are also opportunities which we will explore in this report—opportunities to help make science and research in Canada more inclusive, collaborative, open, interdisciplinary and reflective.

2. DIRECTIONS FOR SCIENCE AND RESEARCH IN CANADA

Today, science happens on a variety of scales. Scientific initiatives can occur on a national level, as facilitated by large institutions like governments (including federal and provincial agencies and departments), industries (such as multinational and domestic companies, as well as start-ups), and academic institutions (including post-secondary institutions, CEGEPs, research hospitals, and colleges). However, science can also occur on smaller scales, facilitated by local community-based initiatives or non-profits. Collectively, these organizations provide unique and critical contributions to science and innovation in Canada and beyond.

Maintaining a healthy scientific ecosystem provides Canada with autonomy and the nimbleness to tackle current and future challenges, such as responding to future pandemics. While the economic advantages to centring Canada's scientific strategy on applied research and industry priorities may seem clear, it is equally vital that fundamental and exploratory research be supported, given that scientific breakthroughs and world-changing innovations can happen in unexpected places.

For example, in the 1990s,[18] researchers found unusual repetitive sequences in DNA across bacteria. These repeats are now known to be major loci involved in CRISPR-Cas, a system where the enzyme Cas, akin to a pair of molecular scissors, can be used to edit genes in different organisms. Similarly, researchers, including Dr. Katalin Karikó and Dr. Drew Weissman, discovered how to engineer mRNA (a molecule which carries instructions for making proteins) so that it could be used to produce specific proteins in a living organism. Along with the work of Dr. Pieter Cullis (at the University of British Columbia) in developing lipid nanoparticles for drug delivery, these discoveries were critical in the rapid development of both the Pfizer/BioNTech and Moderna COVID-19 mRNA vaccines.

Ultimately, it is hard to predict the future applications of fundamental research, but without these key discoveries, the world would be completely different, and not for the better.

2.1 How do we select research priorities?

The system[19] of selecting research priorities (i.e., which research priorities are supported and which research actors are credited) stands as a strong indicator of what and who, as a society, we value in a scientific context.

When it comes to science and research in Canada, a major source of funding and support comes from the federal government, with many of the commitments outlined in annual federal budgets. For example, in 2018,[20] there was a historic federal budget which made substantial investments in fundamental research, followed by commitments to expand support for research trainees in 2019.[21]

There was no budget announced in 2020, but there were ongoing investments in Canadian science throughout the pandemic. In the 2021 federal budget,[22] science underpinned targeted investments, including artificial intelligence, quantum technologies and bio-innovation, while the 2022 federal budget[23] focused heavily on investments to accelerate innovation and build intellectual property, and smaller investments across various disciplines (such as creating targeted scholarships for Black student researchers).

Today, academic and industry researchers alike continue to push for increased support for their respective sectors. But now there is also an increasing number of targeted calls for federal funding, which may lead to fractured or unsustainable research programs and are often outpaced by changing governments. We must ensure that government priorities are balanced, if not aligned, with the needs of fundamental research[24] and early technology development, and that of applied innovation, whose goal is to implement emergent technologies and discoveries.

We believe that achieving a balance between fundamental and applied sciences will ensure that Canada stays internationally competitive in the short, medium and long term. It will be important that this balance consider both community-based and independent research organizations (i.e., entities where research is conducted beyond CEGEPs, universities, industries and government labs), as well as established research organizations like academic institutions, universities and industry. This will ensure that our country is in a position where we are proactively working towards tackling current and future challenges instead of reacting to them. By recognizing science outside traditional institutional boundaries and providing equitable funding to the organizations and actors within, we envision diverse communities leading science initiatives, strengthening research capacity to improve outcomes for those directly impacted, and bringing attention to projects which may be left out through traditional avenues for research.

2.2 Who participates in and benefits from science?

The way we think about the recognition of institutions and individuals also needs to change, including the identification of who does the science (discussed in **section 4**). Recently, there has been a shift towards recognizing[25] diversity and inclusion within research programs, scientific studies, and grant proposals.

However, the inclusion of under-represented voices and communities, without considering equity, justice or fair compensation, is another form of exploitation. This top-down approach also enables researchers with greater power or influence to leverage under-represented communities for personal research gain, such as past situations where Indigenous and racialized researchers and communities have been included in grant applications or manuscripts, but without true informed consent or collaborative power. We note that this issue could stem from the fact that the current system incentivizes diversity but lacks accountability, with little to no follow-up on or measurement of the success of the collaboration from all parties' points of view, and the impacts of the collaboration in the respective areas. Implementing ways of sharing objectives in a SMART[26] manner and measuring its achievement in terms of existing tools (such as a LOGIC model) could be envisioned.

We have always been researchers: Indigenous-led research for the future

Taylor Morriseau: Although Canada is perceived as a leader in science and innovation, this drive for scientific advancement has been fraught with the exploitation of Indigenous lands, knowledge and bodies. To break this cycle of over-researching and under-serving, Indigenous nations are actively reclaiming and asserting self-determination over research and data sovereignty. In Manitoba, the First Nations Health and Social Secretariat of Manitoba (FNHSSM)[27] is one of these Indigenous-led organizations reclaiming control over the design, implementation and interpretation of health research for over 63 member First Nations in Manitoba.

From developing ethical research standards, to gathering culturally appropriate survey data, to leading community-based participatory research initiatives, organizations like FNHSSM are models for what the future of Indigenous health research should look like in Canada, with equitable funding, support and resources. This includes strengthening capacity for Indigenous researchers like Dr. Wanda Phillips-Beck,[28] who was named Manitoba's first Indigenous Research Chair in Nursing. This is the first time that someone working for a community-based Indigenous organization has received a research chair position – those positions are normally reserved for scientists affiliated with academic institutions.

As Indigenous people, we have always been researchers. The reclamation of research space continues to be an ongoing struggle; however, this recognition is long overdue.

The Inter-Connectedness of Well-being. Credit: First Nations Health and Social Secretariat of Manitoba

2.3 Calls to action: How to build long-term sustainable research

Overall, we suggest developing a vision for Canadian science that strikes a balance between investigator-led research and mission-oriented calls, as well as between fundamental and applied research, leading to long-term and sustainable science and research in Canada. We suggest the following actions:

1. **Integrate different types of knowledge creation and systems.** Non-Western knowledge systems need to be included, protected and credited through both intellectual property and cultural metadata.[29] It is also important to review the eligibility criteria within funding opportunities (e.g., those from federal funding agencies) to ensure that non-Western research and/or community-based organizations are recognized as eligible entities.

2. **Rethink how we evaluate the impact of research, with a dedicated equity lens.** We suggest defining mechanisms (quantitative, qualitative and otherwise) to evaluate the immediate and long-term impacts that knowledge has within (*i*) a specific field and (*ii*) the larger society. This will inform the development of a more holistic evaluation system that recognizes merit beyond performance metrics, such as publications and grants (see section **4.2.1**). We also recommend considering the granularity of approaches when thinking about equity, and making sure the impact of the measures suggested to be implemented can be evaluated (see section **4.2.3**).

3. **Implement mechanisms to de-silo disciplines.** The "hard sciences" (such as physical and life sciences) need to better collaborate with social sciences and humanities. While joint calls for proposals are currently made, we need to give the possibilities and flexibility (in terms of administration and governance) to research organizations to facilitate de-siloing of their disciplines. For example, mechanisms need to be developed so that federal or provincial funding for a student affiliated with two departments from different disciplines are attributed in an equitable manner to both departments.

4. **Provide sustainable funding to support science and research in Canada.** For example, there are larger innovation grant competitions which should continue to be supported, such as the Superclusters Initiative[30] and Canada First Research Excellence Funds,[31] that are geared towards providing resources to create cutting-edge innovation ecosystems and long-term economic advantage. Moreover, to establish and sustain a reliable network of researchers, we must ensure that the scientific and technical expertise on which entities are relying on are well-kept. In other words, we need to create sustainable funding programs for researchers. One urgent need would be to put in place, and sustain, long-term funding mechanisms for research professionals in charge of shared instrumentation platforms in universities, who are critical to maintaining the scientific and technical expertise, in addition to ensuring the appropriate training of the highly qualified personnel for specialized equipment.

3. SCIENCE SHOULD BE COLLABORATIVE AND MULTIDISCIPLINARY

Research has become increasingly collaborative. For example, the number of authors listed in academic publications has increased five-fold over the last 100 years,[32] with some recent papers listing over 1,000 authors.[33] This points to the increasingly collaborative nature of science and the growing need for infrastructure to support and incentivize collaboration. And, as illustrated by the COVID-19 pandemic, the complexity and time-sensitive nature of large-scale challenges require coordinated and collaborative efforts.

3.1 Barriers to collaboration

There are several barriers[34] to implementing opportunities for collaboration. For example, the potential for a collaboration is often reliant on a researcher's own professional and social networks. Navigating this closed-door landscape can be difficult, especially for women.[35] This is further complicated by additional risks. Researchers are under significant pressure to publish regularly, and may be hesitant[36] to share ideas at the risk of having them stolen. Intellectual property agreements can also be difficult to develop at both national and international levels.

The competitive nature of research negatively impacts collaboration, idea sharing and collective pursuit of knowledge. Several initiatives are being undertaken to improve the collaborative aspects of the academic environment. For example, organizations like Mitacs[37] and the Natural Science and Engineering Research Council's Collaborative Research and Training Experience (CREATE)[38] program help support innovation and facilitate collaborations between industry and academia. CIFAR[39] supports researchers and knowledge mobilization efforts, with an eye towards high-risk, high-reward outcomes. There are also broader, ongoing discussions about Slow Research,[40] which seek to re-address how we approach science and research in the first place.

International community research to learn from grassroots pandemic efforts

Chelsie Johnson: The TAIBU Community Health Centre[51] and the University of Toronto have partnered with stakeholders in Toronto, Canada; São Paulo, Brazil; and Brighton, UK to collaborate on the research project Building Back Better from Below (B4): Harnessing Innovations in Community Response and Intersectoral Collaboration for Health and Food Justice Beyond the COVID-19 Pandemic.

This Trans-Atlantic collaboration will combine insights from social science research and the lived experiences of activists, social entrepreneurs, front-line workers and local public officials to identify strategies for future action to disrupt entrenched patterns of inequity, and secure health rights and food justice after the pandemic. We recognize the intersecting nature of the health, food equity and democratic representation challenges brought forward by the pandemic. Therefore, we will take an action research approach to analyzing the trajectories, outcomes and sustainability of grassroots innovations and collaborations that have emerged since March 2020 among activists and front-line service providers working with marginalized and racialized communities in the three above-mentioned cities, which are socially diverse and economically dynamic but marked by inequality.

Our overarching research questions are these: How can grassroots innovations and multi-stakeholder collaborations that developed during the COVID-19 pandemic in São Paulo, Toronto and Brighton be sustained? What lessons from their experiences can be incorporated into strategies to sustain effective intersectoral post-pandemic responses to the challenges of health equity, food security and democratic representation in highly unequal urban settings on both sides of the Atlantic?

3.2 Science is global

International collaborations continue to grow.[41] Longstanding data have shown that international co-authorship of research publications leads to higher citation[42] rates than domestic authorship (though this may be due to more established researchers having better access to international collaborations).

Undoubtedly, better sharing of information is a beneficial outcome of international cooperation—and one that extends beyond academic research and publication. One high-profile example of international collaboration is in response to the global COVID-19 pandemic.[43] As of April 2022, the most commonly administered COVID-19 vaccine in Canada[44] was the result of international collaboration[45] between industry partners headquartered in Canada, Germany and the United States—all based on sequencing data. The technologies that made this vaccine possible were based on decades of work undertaken at the University of British Columbia[46] and the University of Pennsylvania.[47] Organizations such as Coalition for Epidemic Preparedness Innovations (CEPI)[48] are fostering continued international cooperation to address future epidemics. There are also scientists who trained in Canada and are now abroad. This scientific diaspora offers the potential to redefine the role that science and technology plays internationally and strengthen Canada's international partnerships through science diplomacy. The benefits of international collaboration are clear, but it is up to decision makers, across sectors, to encourage and foster these relationships through support for programs similar to CEPI and through expanded research and study abroad programs for scientists at all levels (such as the Canada-China Scholar Exchange Program[49] and the Study in Canada Scholarships).[50]

Youth Council member Chelsie Johnson and the Board of Directors of TAIBU Community Health Centre

Slow Science: Reflection versus speed?

Landon Getz: Science doesn't provide us with the answer to what we *should* do, only what might happen after we make a choice. A variety of other disciplines are involved in deciding what we should do, including political science, ethics, social sciences and the humanities.

Slow Science is a reference to the popular "Slow Food" movement, which began as opposition to the growing fast food industry across the globe. Today Slow Food (and indeed Slow Science) focuses less on speed and more on holistic approaches to food that, according to the philosophy of Slow Food International, are **good**, **clean** and **fair**. In my perspective, when we do Slow Science, we are more reflective about how our science impacts the world beyond just the work itself, and we try to incorporate some of the disciplines that help us decide what we should do, ultimately to decide how we want to do our science, what science to do, and why that science matters on a broader scale.

I have used this Slow Science framework to bring my microbial genetics background and deep interest in ethics to a number of conversations around genetic editing of nature and ourselves. I think it is important for scientists to consider how their work might be used and whether these uses are things we want, or are ready for.

3.3 Moving towards multi-sectoral research

Challenges with collaboration also occur between academia and other sectors. While knowledge creation happens everywhere, much of the funding and recognition of knowledge creation has been historically centred around academia[52] and recognized via academic publications. Other sectors that regularly create and hold knowledge include industry, government, non-profits, grassroots organizations, and communities.

There are several challenges to consider here. Firstly, the distribution of funds, knowledge rights, and self-direction remains a challenge for intersectoral collaboration. Industries, governments and academic institutions are prioritized for funding distribution, with little to no independence for non-profits, grassroots organizations and communities. These issues create hostility between sectors, reducing both the retention of cross-sectoral experts and interest in pursuing collaborative efforts. For example, instead of supporting independent or truly collaborative knowledge creation, communities are often exploited for research gain.[53] Lastly, misaligned goals between potential industry and academic partners may create obstacles for collaboration between sectors. The largest challenges can be seen as time constraints, issues related to intellectual property negotiations, differences in innovation culture, as well as a lack of awareness or exposure of research activities between industry and academia. Nevertheless, academia and industry both value research publication and research and development (R&D). A shift is therefore needed from an academic-centric knowledge creation focus to a decentralized model of knowledge recognition.

Furthermore, the pandemic has slowed economic progress and has put severe pressure on public finances. Though this may strain public investment opportunities in research, it expands the opportunity for further coordination and collaboration with Canada's private sector in applied and basic research. As discussed in **section 2.1**, applied research is important to bringing innovations to Canadians, but basic research expands the knowledge for scientific progress. Improved targeting of investment to basic research, coupled with closer public–private partnerships, could increase productivity growth at a lower cost to public finances. The importance of this level of cooperation and collaboration between sectors was recognized in the 2021 federal budget in which specific funds were allocated to building necessary infrastructure to manufacture vaccines domestically.[22] While this level of cooperation in R&D streamlines access and availability of innovations to Canadians, it is a tool still underutilized, and science culture should advance to reflect it.

The knowledge generated at academic institutions across Canada also impacts how issues get prioritized, politicized and funded. This highlights why collaboration between scientists and economists are so important and need to be strengthened. Science needs to be better integrated into economic policies and economics needs to be better considered by scientists in order to guide and inform policy decisions.

Bridging disciplines: Airplanes, design and modelling

Andréa Cartile: I am a PhD student researching ways in which to model the airplane design process. Airplanes are complicated machines involving hundreds of thousands of parts and millions of lines of programming code. Airplanes are developed over 6–7 years involving thousands of experts from all over the world in many different disciplines, and the development process typically costs several billion dollars. Airplanes also, by law, have to be safe, which accounts for a big portion of the development time and cost. While there are commercially available software solutions that try to help manage this process, there are still many challenges that remain unsolved. My research aims to develop a model that better reflects the complexity of the aircraft design process so that it can be used to develop a software solution that better supports the process.

I am very fortunate to be doing industry-based research, and am funded by both industry and the Natural Sciences and Engineering Research Council of Canada (NSERC)! I have the opportunity to consult with two different aerospace companies and receive feedback from a wide range of multidisciplinary aerospace experts. I find that taking an academic research approach to an applied industrial challenge is the best of two worlds, as I am receiving well-rounded training and experiences.

3.4 Academic training and multidisciplinarity

Multidisciplinary approaches involve researchers approaching problems from their own fields and working together to investigate problems. Interdisciplinary approaches typically involve researchers approaching problems between disciplines, moving outside the boundaries of their own fields. While multidisciplinary and interdisciplinary collaboration is beneficial, its implementation within academic education and research faces several challenges.[54]

The siloed nature of universities is reflected in the separation of the federal funding agencies, where social sciences are treated as separate[55] from the natural and health sciences. Watershed events like the COVID-19 pandemic have emphasized the need[56] for "multidisciplinary, globally coordinated approach[es] that [support] harmonized, large-scale studies that have the power to provide robust evidence to inform policy." Multidisciplinarity and interdisciplinarity remain recurring topics[57,58] of discussion within academia in an attempt to address the deeply siloed structures of its disciplines. De-siloing of research opens windows of opportunities for cross-sectoral efficiency[59] and productivity previously unimagined.

Multidisciplinarity also means finding more spaces for issues like ethics, social science and humanities, which are undoubtedly important to the scientific process but are often excluded from scientific spaces. Science does not occur in a vacuum, and these fields provide context and guidelines for good and responsible research. For example, systematic studies of new innovations by economists and other social scientists begin out of a concern with improving quantitative knowledge of the *sources* of economic growth. Principles in economics show that conventional factors of production (capital and labour) account for merely a modest share of economic growth and, thus, propel an interest in understanding why market mechanisms are not as well suited to allocate resources for the production and transmission of knowledge as they are for more traditional goods and services. Other examples of multidisciplinary approaches include incorporating tools from one discipline into another, such as using artificial intelligence in the field of chemistry or developing software tools to support aircraft design. Graduate training should provide avenues for adopting tools and techniques from other disciplines to advance a field of research.

Bridging science and law

Sophie Poirier: I'm a second-year law student at University of Montreal and a student at Lavery, a renowned Quebec firm. Before studying law, I studied Health Science in CEGEP. Even though I now study in a non-scientific field, my previous studies allowed me to recognize the importance of considering scientific sources in all fields.

In my law classes, I thrived on learning about consent to care, medical assistance in dying and institutional care. I learned about the importance of considering science to create the most accurate laws possible. However, there is still a gap between theoretical laws and their application in a medical setting. This is one of many examples where bridging science and law can be impactful.

This year, I worked for Pr. Regis and the H-POD[60] on a research project to explore the normative impact of the World Health Organization (WHO) in domestic law. More precisely, this project analyzed the laws, regulations and jurisprudence of different countries with the goal to compare the approach of these countries towards the WHO recommendations. This unique project links science-based recommendations to the law that impacts our everyday lives. More pluridisciplinary projects, like this one, would greatly benefit our society.

The current research and academic infrastructure is rigid, siloed and institutionalized, and remains inadequate for collaborations between people in specific disciplines. Siloed research can result in fragmented long-term research efforts that span many fields. For example, vaccine development and delivery require coordinated efforts in biochemistry, virology and public health, to name a few. Similarly, climate change is an urgent issue and sprawls across countless disciplines. The siloing of data, researchers and motivations will only restrict the ability for Canada to realize solutions to problems of this scale. We believe that promoting the de-siloing of research disciplines and those involved (beyond the current academic, industrial and governmental researchers; see **section 2.2**) could contribute to normalizing a multidisciplinary approach to current issues and ensure the inclusion of multiple types of entities where research is conducted.

A logical point of entry is with trainees, but currently undergraduate degrees can be inflexible and limited to program-specific subjects. Graduate students often do not have the required support to undertake multidisciplinary projects, due to limited funding, lack of access to courses outside the primary degree domain, lack of available multidisciplinary supervision or limitations on multidisciplinary evaluation committees. This, of course, differs across universities and graduate programs, which can cause inequalities among those studying the same specialty.

Collaborating to accelerate discoveries: The Institut Courtois at the Université de Montréal

Audrey Laventure: The Institut Courtois,[61] a new institute created following the exceptional $159 million gift from the Fondation Courtois to the Faculty of Arts and Sciences at the Université de Montréal, will contribute to merging three different disciplines: chemistry, physics and informatics. The Institut Courtois will provide a stimulating and collaborative environment that will give us the means and, above all, the freedom, to push back the current limits of our knowledge on materials and thus ensure future breakthroughs allowing us to exploit their full potential.

The Institut Courtois will serve as an anchor for mobilizing initiatives in materials. By making greater use of artificial intelligence tools and by joining forces with the materials community, professors, research professionals and students will be able to develop a scientific program based on fundamental research capable of responding to the major challenges of the 21st century, such as creating greener batteries and finding substitutes for polluting minerals to be extracted, preparing 3D printed functional objects, contributing to the development of the quantum computer, and robotizing our processes, to name a few.

As the Canada Research Chair in Functional Polymer Materials, one of my research goals is to accelerate research in additive manufacturing of objects with complex 3D architectures presenting functional properties. Artificial intelligence resources are essential for rapid exploration of the conditions that lead to the desired structure–processing–property relationships.

On behalf of the interdisciplinary team that helped envision this project, I would like to emphasize that the Institut Courtois will encourage risk-taking and innovation, and that it is extremely exciting to be part of this scientific adventure which will lead to great discoveries.

Youth Council member Audrey Laventure working in her laboratory

3.5 Calls to action: How to foster global, multi-sector interdisciplinary research

1. **Measure the success of relationships and collaboration between sectors, with a focus on research agency, independence, recognition, accessible funding and support.** Collaborative success should be measured according to the most relevant impacts for each of the involved knowledge groups. These metrics should be expanded from academic-centric publications to include other impact factors most important to each knowledge group. We must also fund more intersectoral programs, such as FRQNT Visage municipal,[62] where researchers can collaborate with cities to promote bridges between academia, administrative organizations and people living in this city.

2. **Improve funding for non-academic sectors.** We must increase access to funding, and recognition for knowledge generation from non-profits, grassroots organizations, and communities should be sought. Increased prioritization, access and availability of collaborative grants with formalized assessments of benefits for each collaborator group would improve accountability; these effective and measurable strategies can be implemented across any type of collaboration. Some additional benefits to intersectoral cooperation include better access to support infrastructures for conducting international work, intellectual property expertise, administrators and impact assessments.

3. **Create and sustainably fund embedded training opportunities within higher education to promote movement between disciplines and sectors.** Education and research should move away from traditional disciplines and more towards holistic skill-based training where a person can acquire the knowledge necessary to solve real-world problems. This can be further supported by academic institutions partnering with industry, government, non-profit, grassroots organization and community leaders to provide internships or co-op opportunities where students can be exposed to multiple sectors related to their studies. These training opportunities could explore niche areas such as policy, science diplomacy, science communication, entrepreneurship, technology transfer and intellectual property.

4. **Enhance the role of public–private partnerships to achieve better integration of science in public policy.** For example, CIRANO in Quebec works to contribute to the strategic decision making of its governmental, parapublic and private partners by producing and transferring university knowledge.

5. **Create more opportunities for research exchange programs both in Canada and abroad, and increase support for existing exchange programs.** Building international relationships and promoting knowledge sharing at all levels of science can lead to fruitful research partnerships across all sectors. For example, the Mitacs Globalink program offers travel funding between Canada and international partners for students and postdoctoral fellows to do research. Ongoing work on this issues includes the Council of Canadian Academies expert panel examining best practices in selecting international science, technology and innovation partners.

4. PATHWAYS TO SCIENCE

Traditional pathways to careers in science have historically been exclusionary to different communities due to various legislative, financial and societal barriers. While efforts to increase participation in science by equity-seeking groups are underway, the linear, "pipeline"-like model fails to portray today's reality of science careers and is intrinsically limiting[63–65] as to who becomes[66] a scientist.

As described by Batchelor et al., "a contemporary approach to science careers should look more like a collection of paths which adapt to the needs of the individual," also known as a braided river model (Figure 1).[67] Just as a river is fed by multiple streams and watersheds, the scientific workforce should be made up of, and accessible to, people from different cultures, backgrounds, socio-economic statuses and educational/employment experiences. This braided river workforce[67] "means creating ways to support, retain, and, as necessary, re-engage science professionals, whatever their route, wherever they join, and whatever the speed of their journey." The world continues to change, and so must the scientific community.

This change needed within and by the scientific community must occur at multiple points and levels in order to transition from the ingrained pipeline-like workforce model to that of a braided river. This involves considering the pathways *to* science, the pathways *through* the landscape of scientific and academic training, and the pathways *within and beyond* academia. These dimensions not only shape how we interact with science and the scientific careers pursued by individuals; they ultimately impact who interacts with science, who becomes a scientist and who advances as a scientist.

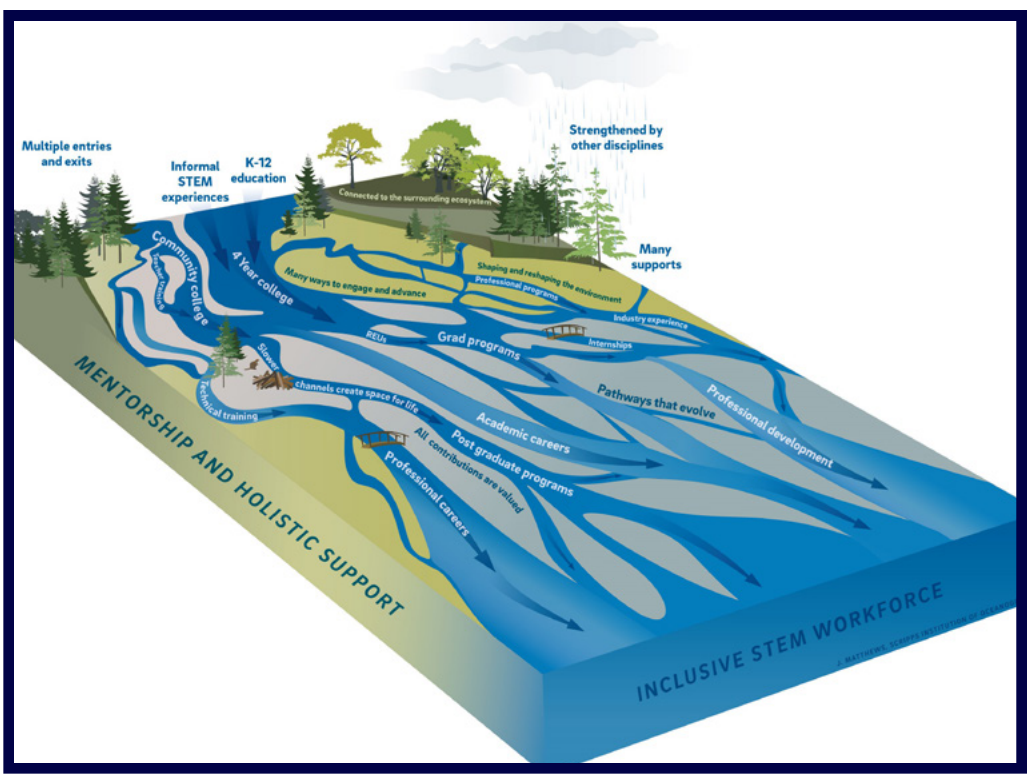


Figure 1: A braided river system illustrates a new, holistic STEM workforce career development model. Credit: Jennifer Matthews, Scripps Institution of Oceanography.[67]

Natasha Jakac-Sinclair, health economist

Natasha Jakac-Sinclair: I work in the field of health economics—a field that tries to assess the value of new health technologies, relative to what is already available in society. I love this field because it forces me to understand problems not just through a scientific lens (i.e., reading the results from a clinical trial), but understand problems through the intersection of science with politics, finance and economics (e.g., why pay for the drug?).

I got here by initially studying biology. Throughout my undergraduate degree, I was exposed to contentious scientific issues, such as gene editing, in the lab and by having conversations with friends. I was also an avid Model UN-er (Model United Nations). So, I brought topics like designer babies to the table for debate. This pushed science beyond academia, and inspired me to pursue a Master's that allowed me to continuously operate at the crossroads of science and policy. My school also collaborated with industry to provide internships for students and taught me how to implement solutions that impact how people interact with the healthcare system.

My experience shows how many disciplines and extracurriculars helped to shape how I view the role of science in society as a multidimensional field.

The intersection of engineering, business development and policy

Ali Sbayte: I am an electrical engineer who likes the sweet spot between engineering, business development and policy. Having graduated in engineering, I feel like I have developed the right mindset and gained the knowledge needed to solve world problems by applying scientific concepts.

I have worked in Japan and gained technical expertise in autonomous driving development as a software developer. I then decided to co-found a start-up in the green tech sector to reduce plastic waste. As an avid team player with strong leadership skills in project development and management, as well as technical expertise, I worked on a project at a start-up to prototype and develop the hardware of a 100% fully electric urban truck. Today, I work as a software developer in the utility sector.

In doing so, I have worked closely with other engineers and scientists, and I understand the importance of policy in the energy sector. I also took extracurricular courses on entrepreneurship. Inevitably, a well-rounded set of personal experiences and working with people with different backgrounds is necessary in solving real-world problems, especially in today's interconnected world.

Finding my place in science

Sara Guzman: In 2019, I completed a Bachelor of Science, with a major in biology and minor in chemistry, at Vancouver Island University (VIU). Like many people, once I graduated, I was frustrated because I had no idea what I wanted to do with my life. I applied for a lot of different jobs that I was interested in, including a unique drug-checking technician position at the BC Centre on Substance Use (BCCSU).

To my surprise, I got the job at BCCSU, and I was one of the first chemists on the project (and the first female drug checking technician). For two years, I developed training materials and used my chemistry knowledge to provide an innovative harm reduction service on the frontline of the overdose crisis in British Columbia. By using a spectrometer and immunoassay test strips, I tested a variety of substances (including illicit drugs) to help people who use drugs make more informed decisions. This experience helped me understand how research works outside of an academic or laboratory setting. It was my first introduction to how research can help better inform policy and service provision, and it gave me the opportunity to witness how scientific developments impact public health.

Although I wanted to keep making a difference in the ongoing overdose crisis, I also wanted to expand my knowledge and apply more of my chemistry skills. I left the BCCSU and I am now working as a chemist with Health Canada's Strategic Research and Scientific Development team. I have unlimited access to different technologies, which I use to analyze and quantify controlled substances, as well as to elucidate psychoactive compounds and precursors new to the illicit drug market.

After working for several years after my undergraduate degree, I have found a field in chemistry that I am truly passionate about. This fall, I will be starting graduate school in chemistry at the University of British Columbia, where I will be focusing on automated monitoring of reaction mechanisms, new psychoactive substances (NPS), and the synthetic pathways used in clandestine laboratories. I am hoping that, during and after my studies, I can implement cutting-edge research in projects that can have a direct impact on public policy, health and safety. I also hope to contribute to synthesis profiling research that will reach diverse groups in government, academia and the public.

4.1 On-ramps to science

Multiplying on-ramps to science allows for different people to engage with science, and to do so at different times in their lives. This can start from classrooms in elementary, middle and high schools where, in some cases, an update is needed when it comes to the approach to teaching science. For example, students have previously said that climate education is inconsistent,[68] and that textbooks are often outdated. As noted by Let's Talk Science,[69] less than 50% of high school students graduate with senior STEM courses, yet about 70% of Canada's jobs, from health care to skilled trades, now require some level of STEM education. In addition, current science curricula can shape the perceptions of science careers by exposing children to stereotypes, a limited view of the value of science in society and western-centred ideas of science that minimize Indigenous ways of knowing which consider a more holistic, relational and intergenerational approach to knowledge.

By revamping science curricula, we can reflect the changing nature of science in our society, and equip the next generation of scientists and workers with the critical skills needed to tackle emerging global challenges, from climate action to future pandemics. To do so, we must review or complement current K–12 education and ensure that we are supporting, and recognizing, the efforts of teachers who go above and beyond to foster curiosity and a passion for science among students.

But discovering science and its methods does not need to be limited to K–12 science classes. It can come from a variety of engagement opportunities and informal STEM experiences, including community-based participatory programs, technical programs, academic and industrial internships, continuing education, mentorship programs, the intersection of science with other disciplines, and more. By engaging children and youth in different contexts, we can debunk the perception that STEM careers are only for specific subsets of the population.

There is no shortage of informal STEM experiences across Canada

E2 adventures[70] is a Canadian non-profit organization which runs live, interactive, virtual field trips to help teachers, schools and school boards connect their curriculum with real-life applications. By working with a variety of companies, their team takes students from coast to coast on explorations of systems to see how science, tech, engineering, arts and math apply to the real world.

Let's Talk Science[71] is a national charitable organization committed to preparing youth for evolving career and citizenship demands in a rapidly changing world. They do this by working with universities, colleges and research institutes and over 3,000 volunteers, to bring science outreach to Canadian youth.

Soapbox Science[72] is an outreach platform for promoting women and non-binary scientists and the science they do. Their events transform public areas into an arena for public learning and scientific debate, where everyone has the opportunity to enjoy, learn from, heckle, question, probe, interact with and be inspired by leading scientists.

Visions of Science Network for Learning[73] is a charitable organization that aims to advance the educational achievements and positive development of youth from low-income and marginalized communities through meaningful engagement in STEM fields and research. It does this through outreach workshops, in-school enrichment and community STEM clubs, and by supporting the development of STEM community leaders.

Youth Council member Keeley Aird at a STEM Kids Rock event

Getting kids interested in science, outside of the classroom

Keeley Aird: The route to a career in science is oftentimes thought of as being difficult.

Science and math are two subjects that you either identify as being "good" or "bad" at.

This perception is what I want to change through my organization, STEM Kids Rock (SKR).

As an elementary/high school student, I struggled with science and was told that science wasn't for me by many teachers and counsellors who thought they were guiding me toward subjects I would be "textbook smart" in. The assumption was that grades indicated your success and future career pathway.

My parents, not science or math people, brought my brother and me at an early age to science centres, zoos and museums because they saw the joy we found in learning anything and everything. This informal learning experience was a game-changer for me. It gave me the resilience to persevere through the STEM school pathway. It eventually led me to McMaster University. I am currently studying Honours Earth and Environmental Sciences and working towards getting my Professional Geoscientist Certificate (PGO), so I can be a geologist.

I realize that not many kids have the flexibility to learn outside of the classroom like I did. With SKR, we bring the Science Centre, the ROM and the informal STEM experiences to kids.

Just because something isn't in your curriculum doesn't mean you shouldn't learn about it.

Through free and informal STEM outreaches, SKR is able to start conversations about science with kids. SKR provides kids with tables that are overflowing with fossils, exotic insects and rocks/minerals that are able to be touched, held and experienced by anyone. This sparks that initial interest and enables kids to ask more questions and develop new ideas. It helps create future scientists!

There are so many kids that are passionate about dinosaurs, planets, fossils and rocks, and they want to share their knowledge in the classroom. However, they find themselves being told, "not now, we will learn about that later." SKR gives these kids the opportunity to put on a lab coat and share their knowledge while having fun conversations with their peers. Letting kids be educators at a young age empowers them, despite what might be happening in the classroom, and sparks their lifelong science journey.

4.2 Strengthening pathways in the landscape of scientific and academic training

4.2.1 Re-defining "research excellence"

When it comes to applying for opportunities in science and research, defining success is often limited to "research excellence"[74] —that is, quantifying the number of past grants awarded, publications produced and students supervised. A similar approach exists for awards and scholarships, where the number of past scholarships received and past research contributions weigh heavily in evaluation. This fails to capture the scope of scientific impact within society and promotes a culture of exploitation, fraud, elitism and competition. It also perpetuates a science culture that often overlooks the life experiences of those who do not follow the traditional career trajectory. While it may be tempting to uphold the illusion of a scientific "meritocracy" by placing outsized emphasis on academic and publication records, simply centring these criteria without the context of life experience and societal biases means that opportunities are not granted equally across all communities.

The definition of excellence places constraints, namely on who is supported and promoted in their career advancement, and also on who shapes the science landscape in Canada. Additionally, the emphasis on academic and publication records does not allow for learning through failure, nor does it account for the wealth of knowledge that remains unshared due to an undervaluing of negative or inconclusive experimental results. The COVID-19 pandemic has laid bare the shortcomings of current STEM training in its often singular focus on peer-reviewed publication or academic record as measures of excellence. When the larger society is not engaged with science through effective and inclusive science communication and outreach, distrust in science and scientists can fester. Scientific knowledge must be shared beyond academia and research communities; thus the importance of science communication and policy must be elevated accordingly. We must reorient science education, training and research in a way that values excellence in different shapes and forms, including community engagement and service, policy development and science communication.

4.2.2 Graduate-level and post-doctoral scholarships and fellowships

Graduate students and post-doctoral fellows are an integral part of science and research in Canada. At the graduate school level, Canada currently fosters and attracts domestic and international talent through grants, awards and scholarships from the federal funding agencies (i.e., the Natural Sciences and Engineering Research Council of Canada, Canadian Institute of Health Research and Social Sciences and Humanities Research Council).

But there are several disparities present in both graduate-level and post-doctoral scholarships and fellowships. Per a recent analysis,[75] individuals from under-represented groups, with a master's or doctoral degree (including women, visible minorities, Indigenous peoples, and people with disabilities) are not being proportionately represented in the federal award processes. Additionally, federal grants are long overdue[76,77] for a significant increase in funding to keep pace with increasing living costs across Canada. This was also raised as an issue during different witness testimonies[78] for the study led by the Standing Committee on Science and Research[79] to explore successes, challenges and opportunities for science in Canada in early 2022.

The disbursement of higher-value "prestige" scholarships, such as the Vanier and Banting awards, furthers financial disparities among students. For example, a 2018–19 Science & Policy Exchange survey[80] found that a majority of trainees wanted to increase the total number of awards (91%), increase the value of awards (79%), and extend eligibility periods for awards (72%). These changes would make awards available to more students, and allow students nearing the end of their graduate degrees to access awards too. When asked whether prestige awards should remain, given that they provide more value and prestige to select trainees but require a larger investment from the federal funding agencies, 62% favoured the reduction or abolition of these awards in favour of more standard awards.

Ultimately, we must question the role of different levels of scholarships and envision how to go beyond the current model of support in order to ensure that all trainees are adequately supported.

4.2.3 Positive changes towards implementing equity, diversity and inclusion

There are several systemic and institutional barriers embedded within scientific and academic training. These barriers must be dismantled, since historically the people contributing to Canadian science have not been representative of the community at large. It remains true today that there are significant barriers to Canadian science for those who belong to marginalized groups in science, which includes, but is not limited to, women, people of colour and Indigenous, disabled and 2SLGBTQIA+ people.[b]

When it comes to gender equity in science, the representation of women among university faculty[81] has increased over the last 50 years, yet women are still under-represented at almost every level,[82] especially in decision-making roles and senior faculty positions. Beyond academia, the picture isn't much better. A gender analysis by Statistics Canada revealed[83] that male STEM graduates were more likely to be employed in a STEM occupation.

Studies repeatedly demonstrate that women face a number of institutional barriers[15] impacting their experience in the STEM fields. These barriers are amplified for scientists who are Black, Indigenous, and women and gender minorities of colour, who must also navigate a hostile obstacle course.[84] For example, a 2021 report from the University of Victoria[85] found that members of under-represented groups often report an unwelcoming climate in STEM programs, which negates a positive learning environment and positive experiences.

A 2021 US study[86] identified that LGBTQ individuals experienced higher social exclusion and professional devaluation in STEM, compared to their straight counterparts. This study also identified that LGBTQ+ individuals in STEM were more likely to have thoughts about or plans to leave their STEM profession than their straight counterparts. This study used data collected from 21 United States–based STEM-related societies, but likely identifies a problem that is widespread among the STEM professions, and is not limited just to the United States. Though Canada is home to roughly[87] one million LGBTQ2+ people, data and analysis of this kind are not available for a Canadian demographic.

A number of recent initiatives launched from federal funding agencies in Canada aim to bridge the gap in equity, diversity and inclusion (EDI) progress across Canada. Initiatives like the Dimensions pilot

b In the context of this report we primarily used the acronym 2SLGBTQIA+, standing for *two-spirit, lesbian, gay, bisexual, transgender, queer, intersex and asexual*. Although this term is commonly used in Canada, it is not uniformly used across the country and in other nations. Hence, within the context of this document, we used various acronyms that were specific to the references used, since the communities surveyed might have been different.

project[25,88] or recent updates to the Tri-Council's self-identification questionnaire to start collecting data on LGBTQ2+ individuals are working towards a more equitable, diverse and inclusive science.

But we can go further still. If people are being pushed out of science, or are not given opportunities to enter and advance in science, it means that we are failing to make adequate progress on equity and inclusion efforts. The next big, life-changing breakthrough could potentially be missed because of these failures—but more importantly, everyone deserves the opportunity to pursue their passions and to enjoy the dignity of a workplace free of discrimination.

Supporting, promoting and fostering a community of women in physics

Marie-Eve Boulanger: The Women in Physics Canada conference (WiPC) and its undergraduate counterpart are great examples of how actions can be taken to promote diversity, equity and inclusion in traditionally male-dominated fields. These professional conferences aim to create a space where participants can build networks, explore career paths, and present research, while also promoting gender equity and taking part in a conversation about women in physics, mental health and LGBTQ+ issues.

I co-organized the 7th edition of the Women in Physics Canada conference,[89] which was held in 2018 in Sherbrooke. This national conference brought together more than a hundred individuals from the student community as well as faculty, postdoctoral researchers and professionals from the private sector working in physics-related fields. The success of this event extends far beyond the participants: it gave impetus to diversity-related initiatives[90] within Université de Sherbrooke's Physics Department.

I also co-organized, with my fellow youth council member **Madison Rilling**, the 2nd edition of the Canadian Conference for Undergraduate Women in Physics (CCUWiP),[91] which was held in Quebec City in 2015. This event shares many of the goals of the WiPC conferences and, in particular, aims to guide undergraduate students along their academic or non-academic career paths in physics. This Canadian initiative was born at McGill University, where Madison co-organized the very first edition in 2014.

QAtCanSTEM: Queer Atlantic Canadian Science, Technology, Engineering, and Mathematics

Landon Getz: I started Queer Atlantic Canadian Science, Technology, Engineering, and Mathematics (QAtCanSTEM) in 2019 as an ad-hoc group to begin addressing the lack of community the 2SLGBTQIA+ folks in STEM in Canada often experience, especially considering the geographical size of Canada. At the time, I knew few out Queer professors and academics, and I often heard from peers that they also didn't know folks like them doing STEM.

The motivation for QAtCanSTEM was born out of having been able to experience the LGBTSTEMinar in 2019, hosted at the Institute of Physics in London, UK. LGBTSTEM is a similar organization in the UK, running general science conferences that cater to Queer folks as a safe and inclusive space. Attending in 2019 was such an incredible experience, because for the first time I didn't feel like I had to worry that someone would not accept me for who I was, or would ask me uncomfortable questions about a hypothetical wife or girlfriend. I, and the other attendees, were free to be who we were without question. It was one of the first scientific experiences that I had like this.

QAtCanSTEM has run two annual conferences (in 2020 and 2021) in Atlantic Canada similar to the LGBTSTEMinar, with academic talks, posters, panels and social networking events.

Youth Council member Landon Getz speaking at LGBTSTEMinar in 2019.
Credit: Piers Macdonald

To change the face of science, we must tackle inequities everywhere, even Wikipedia

Farah Qaiser: Wikipedia is the fifth most popular website in the world, garnering over 250 million views per day. This free virtual encyclopedia only exists thanks to Wikipedia's global community of volunteer editors, whose contributions make information accessible.

However, of English-language Wikipedia's million-and-a-half biographies, only around 19% are about women. The gender bias of Wikipedia—along with other geographical, racial and societal biases—are a reflection of its community of editors,[92] as well as the systemic inequities[93] present in the broader world. This is a glaring gap, and also an opportunity: by creating Wikipedia pages, we can ensure that the numerous efforts of women and members of historically excluded communities in science are not overlooked.

Since 2018, I have spent many hours[94] editing and creating new Wikipedia pages about scientists. As an individual, and as a member of 500 Women Scientists,[95] I've also partnered with science centres, museums and academic societies across North America to lead 15 Wikipedia Edit-A-Thons and built a community of over 250 contributors who are committed to tackling these inequalities. Collectively, these 250+ editors have edited and created over 1,000 pages, which have been viewed over 20 million times—in other words, we've created 20 million opportunities to share the stories of scientists and researchers, and slowly change the face of science.

4.3 An inclusive STEM workforce: Pathways within and beyond academia

Efforts to retain and attract domestic and international highly qualified researchers and personnel after completion of training programs must be redoubled through expanding Canada's scientific job market. This includes strengthening and expanding Canada's national and provincial research laboratories.

Moreover, the job market does not always recognize that science training also provides critical skills that are highly applicable beyond traditional STEM careers. A 2021 Council of Canadian Academies' report on the labour market transition of PhD graduates[7] found that business graduates have the highest earnings five years post-graduation, while humanities and science graduates earn the least. This may in part relate to a "skills-awareness gap" which prevents PhD graduates from understanding and describing their value, paired with a mismatch between what PhD holders have to offer and what employers need. The Council of Canadian Academies' report suggested that promising practices included target programs to increase demand for PhD holders among non-academic sector employers. However, it is essential that increased demand comes hand in hand with increased recognition of the value of a PhD by industry, government and other employers beyond academia. Two policy-related programs which share this aim are Mitacs' Canadian Science Policy Fellowship[96] and the Government of Canada's Recruitment of Policy Leaders.[97]

An emerging trend in science careers is that of entrepreneurship. Scientists have considerable entrepreneurial potential as a result of their training and skill set mixed with their capacity for innovation. Initiatives,[98] programs[99] and start-up foundries[100] exist to foster this potential and translate it to business creation, but more can be done to make the entrepreneurial career path more accessible, better supported and more known to scientists early on in their training.

Additionally, university and college science programs should be encouraged to include "science and society," teaching or communications as introductory-level courses, as well as paid internships and shadowing opportunities, in order to encourage trainees to explore careers beyond the traditional research career trajectory. This can include exploring careers in government (be it municipal, provincial or federal), industry and non-profits.

Engaging all of Canada in the emerging space sector

Max King: The Canadian space sector is growing rapidly and needs to incorporate the talent that exists across all provinces and territories. Historically centred in Ontario and Quebec, a prosperous Canadian space sector needs to create jobs in other parts of Canada. In my experience in attending school across three provinces, there is passion for careers in the space industry among students everywhere. This passion is tempered by a lack of visibility into Canadian space contributions, and access to jobs in the sector that are close to home.

With emerging launch capability in the Maritimes, and an increasing number of companies creating private spacecrafts, Canada has the talent pool to employ highly skilled individuals in the space sector in multiple major centres, not only in Ontario and Quebec. Developing policy to support the space sector's continued growth and expansion is essential for Canada to remain competitive in the next generation of space exploration and utilization.

Youth Council member Max King with an Electro-Magnetic Leviator at the German Space Centre

From the clinic to a non-profit: A medical physicist turned executive director

Madison Rilling: By trade, I am both an optical scientist and a medical physicist. While completing my PhD, I worked for two years as a clinical medical physicist in radiation oncology. As an expert in radiation and matter interactions, I was an intrinsic part of an interdisciplinary medical team to make sure that the radiation dose used to treat different types of cancer was delivered in the most precise and optimal way possible.

Though my work was excitingly challenging and fulfilling, my experiences gained outside of the lab[101] ignited my desire to pivot from a purely technical career. In particular, serving as a student advisor to Quebec's Chief Scientist, as well as being the sole student board member of Quebec's research funding agency in natural sciences and engineering (FRQNT),[102] directly positioned me at the interface of science and policy. I became involved in research administration and funding, as well as science and women in STEM-related policy development. I even had the opportunity to interact with elected officials and government ministers. These experiences, paired with science outreach initiatives[103] I co-led, were life-changing: they exposed me to different and important roles that scientists could play *for science*, but beyond academia.

Today, I am leveraging my scientific-based expertise and skill set towards technological and social innovation in my role as Executive Director of Optonique (Quebec's cluster for excellence in optics and photonics).[104] Optonique is a non-profit organization aimed at mobilizing, growing and promoting Québec's rich ecosystem in optics and photonics; it is uniquely positioned to support industry, communicate with government and build bridges with academia. Navigating between those very different worlds, I am now involved daily in an exciting mix of policy, business development, research and innovation, outreach, knowledge brokering and more. Beyond my professional role, I like to think of myself as a science diplomat at heart: I use science, and my training as a scientist, to better connect people.

Tiny solutions to big problems

Molly Sung: I have always been drawn to research that centred on finding solutions to big problems. I trained as a chemist, earning my BSc at the University of British Columbia (UBC) and my PhD at the University of Toronto, working in research labs focusing on making biodegradable plastics and renewable energies. But it was an undergraduate research opportunity with UBC's Pieter Cullis that eventually led me to Acuitas Therapeutics at the beginning of 2020—just as the COVID-19 pandemic was beginning. At Acuitas, I get to work with scientists from all over, in a truly international and multi-sectoral effort, researching solutions that address a multitude of therapeutic needs.

When I was a student, I also spent a lot of time thinking about the relationship between science, society and government. Through my work at the Chemical Institute of Canada[105] and the Toronto Science Policy Network,[106] I worked to encourage more scientists to engage more in politics and policy. And through my volunteer work in politics, I hope to continue to encourage politicians to engage with science more frequently.

4.4 Calls to action: How to build multiple on- and off-ramp pathways to science

1. **Review, or complement, K–12 education as an opportunity to expose children to a broad range of diverse models, and empower youth with the skills to dive into the careers of tomorrow.** For example, during the Canada 2067 consultations,[107] over 1,000 young people noted the importance of personalized learning, as well as the need for mentorship and comfortable spaces. Youth are looking for experiential learning: a way to connect STEM learning to real-life problems in a hands-on way, and by taking advantage of new technologies to transform learning into an interactive and student-centred experience.

2. **Support and recognize K–12 teachers.** Among the recommendations in the Canada 2067 consultations,[107] it was suggested that teachers should have the opportunity to participate in STEM-related professional development at least once per year (if not more), and to be linked to community partners across regions to help form dynamic professional learning communities. It is also important to support teachers, through fair pay and compensation, and recognize teachers who are going above and beyond to support their students, through provincial and federal initiatives such as the Prime Minister's Awards for Teaching Excellence in STEM.[108]

3. **Multiply on-ramps to science by creating and/or supporting more informal STEM experiences.** Invest in and support community programming for STEM education—particularly programs that target under-resourced (including low-income and rural) and marginalized communities. Programs targeted to marginalized communities should be culturally appropriate and relevant; for example, outreach to Indigenous communities should be Indigenous-led.

4. **Re-define "research excellence" to value excellence in all of its different shapes and forms.** We propose that more inclusive metrics,[74] such as community engagement[109] and teaching excellence, should be weighted more heavily across the board when assessing applications. For example, in 2022, Québec's Research Funds (Fonds de recherche du Québec)[110] expanded the criteria of postgraduate research awards and fellowships to include building dialogue between science and society, mobilizing knowledge and disseminating it to a diverse audience.

5. **Change the approach to reviewing "excellence" across processes, including peer review, and evaluation for hiring, promotion and tenure.** While a few initiatives[111] are in place to shift this existing mindset among reviewers (which promotes quantity over quality), we need to ensure that current and future peer reviewers are aware of the most up-to-date practices and any (un)conscious biases they may hold (e.g., via training modules).[112] As a community, we also need to continue the discussion on how to improve the peer review process, both for evaluation committees and scientific literature reviews. This should include rewarding communication of "unsuccessful" experimental work, in addition of "successful" experiments.

6. **Rethink the federal approach to graduate-level and post-doctoral scholarships and fellowships.** Baskaran et al. (2021)[75] make the following recommendations: "1) increase the eligibility duration of the federal awards to match that of the SSHRC doctoral awards, and distribute awards proportionate to the number of applicants in each enrollment bracket; 2) change the evaluation criteria used to grant these awards by equally weighting academic excellence, research potential, and personal and leadership experience; and 3) increase and standardize award values across the [federal funding agencies]." Another possible route to a more equitable funding scheme would be to

eliminate "prestige" scholarships,[113] such as the Vanier and Banting scholarships, which carry significantly larger monetary value, in favour of increasing the overall number of grants available. These recommendations can also be applied to awards and fellowships distributed by provincial governments (e.g., the Ontario Graduate Scholarship), as well as third-party organizations.

7. **Continue to dismantle systemic and institutional barriers which impede the entry, advancement and retention of scientists who belong to historically excluded communities.** A full review of systemic barriers, or a list of recommendations is beyond the scope of this report. We stand by and call on decision makers to review and implement recommendations made by leaders in this space, such as implementing best practices to advance equity within academic institutions[114] and labs[115] alike, hosting inclusive conferences,[116] following through on commitments to support Indigenous research and research training,[117] and better supporting researchers with disabilities.[118,119] Critically, it is also important to include scientists who belong to historically excluded communities in these decision-making processes and ensure that they are given the agency to make necessary changes towards EDI goals.

8. **Provide stable jobs for researchers in Canada by strengthening publicly funded research labs.** By increasing and ensuring stable long-term resource allocation, this will provide additional pathways to retaining Canadian talent post-graduation as well as provide autonomy and nimbleness to Canadian science as we confront ongoing and emerging problems such as climate change and future pandemics.

9. **Normalize the exploration of different careers in science, and make it easier to move in, around, and out of science.** Academic supervisors, departments and institutions must help normalize non-linear career paths or "time off" from research, and incentivize engagement in other sectors and disciplines. For example, departments can provide experiential opportunities to help explore different science careers (such as science policy, education and communication) beyond research via paid internships to build experience, dedicated awards to offset financial barriers, or boot camps and workshops to help build skills. Similarly, non-academic organizations should seek to create learning opportunities, be it through recurring internships or the creation of dedicated training programs.

5. SCIENCE IN SOCIETY

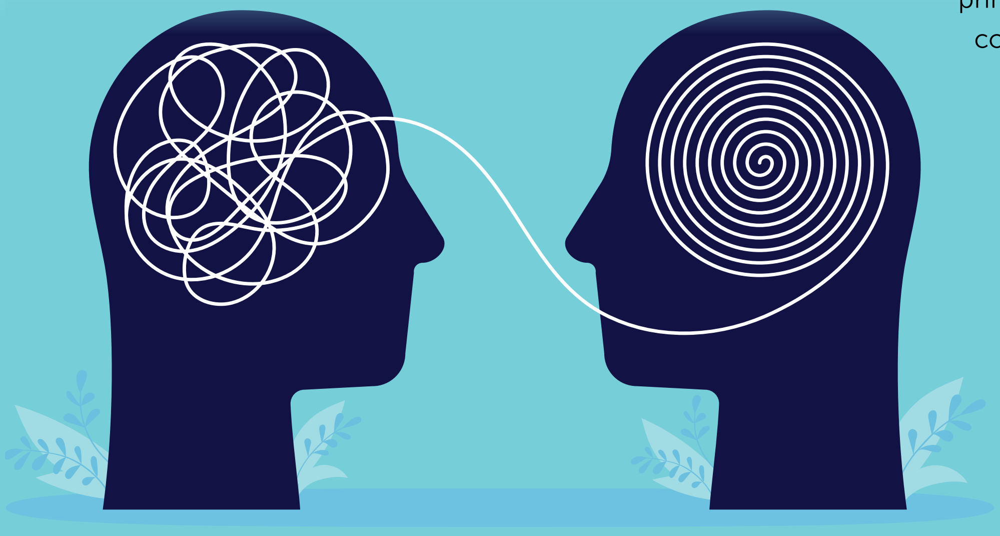
A now-outdated inventory[120] of public science communication initiatives identified over 700 related programs and organizations in Canada, including those led by museums, non-governmental organizations, government programs, media and educational institutions. Despite these numerous efforts, outdated media portrayals tend to persist and emphasize the stereotypical "white lab coat and laboratory" trope.[121] This trope has trickled down to all levels of society. For example, when asked to draw a scientist,[122] more children are drawing women as scientists than ever before. However, when they grow older, children still tend to associate science with men.

Representation matters. If individuals do not see themselves reflected in science or see science as a field that is open and welcoming to people from all walks of life, that can deter them from meaningful engagement with science. Quite simply, those perceptions can act as barriers for individuals to pursue scientific careers, or even engage with science in their daily lives. And so, in this section, we explore different barriers that the broader public may experience when it comes to engaging in science and research, as well as potential opportunities and ways forward.

5.1 Paywalls, jargon and the need for plain language

The convoluted[123] and complex[124] nature of academic publishing has significant ramifications for scientists when it comes to disseminating research findings, but also for the public who have supported science and research with their tax dollars, but cannot access findings due to exorbitant costs.

Beyond paywalls, science is often inaccessible and difficult to navigate due to jargon. Scientists and researchers spend years specializing in a niche discipline, and they master technical terms which are not usually accessible to non-specialist readers. As a result, when it comes to communication and outreach efforts, be it a manuscript or a media interview, scientists often use jargon as a shorthand, and end up alienating or confusing readers and listeners. This even confuses fellow scientists. For example, a 2021 study[125] analyzed jargon in over 20,000 manuscripts, finding that[126] papers with more jargon in their titles and abstracts were cited less often by other researchers. In order to make science more accessible, the solution is not to "dumb down" the science (which is patronizing), but instead to be clearer and to incorporate core principles of inclusive science communication into our efforts.



A Roadmap for Open Science

Open Science[127] is the practice of sharing data, information, tools and research results and eliminating barriers to collaboration. In February 2020, the Office of the Chief Science Advisor issued a Roadmap for Open Science[17] to "provide overarching principles and recommendations to guide Open Science activities" for science and research funded by federal government departments and agencies.

The roadmap was followed up by the publication of a Framework for Implementing Open-by-Default with Federal Government Science (in January 2021),[128] and then a series of Open Science Dialogues (February 2022),[129] in which members of the Chief Science Advisor's Youth Council took part. Here, council members raised a number of issues, including (1) the importance of including youth voices when it comes to the implementation of Open Science; (2) the costs of Open Science are particularly prohibitive to early-career researchers; (3) not all data should be open by default, including health and personal data, and especially where Indigenous data sovereignty need to be safeguarded; and (4) the need to build capacity for safe and long-term data storage.

5.2 A growing appreciation for science communication

In the past decade, there has been a growing appreciation for science communication within the Canadian science community.[130] More and more scientists recognize that publishing science isn't enough, and that to engage meaningfully with stakeholders and the public, we need to do more, starting with ensuring that scientists know the core principles of accessible science communication. For example, in 2020, NSERC awarded its first round of the NSERC Science Communication Skills (Pilot) Grant[131] to support organizations providing science communication skills training to students, fellows and faculty in STEM. Furthermore, there are an increasing number of opportunities and resources [132] to help scientists improve their communication skills.

However, because science has a legacy of inaccessibility due to language, these barriers persist. To improve the accessibility of science, we need to continue implementing mechanisms to ensure that the language of science is accessible, starting from when science is produced and shared. At a minimum, academic manuscripts should be accompanied by plain language abstracts or summaries.

It is also important to create and embed more science communication training opportunities across various career stages. Currently, Laurentian University offers a master's degree or a graduate diploma in Science Communication,[133] the only such graduate program in Canada so far. At both the undergraduate and graduate levels, certain Canadian universities offer science communication courses, such as Simon Fraser University,[134] Guelph University,[135] Queen's University[136] and McGill University.[137] This is a good starting point, but we can go further still and ensure that science communication training is a core staple of all undergraduate and graduate curricula. Too often, students must turn to external programs or initiatives to gain science communication training, which might impose financial barriers for potential trainees. Training opportunities should be readily available within institutions to ensure that the next generation of scientists and workers is able to effectively share science and research, as well as deliver sound science advice to decision makers. It is also critical to equip researchers with the skills they need to mobilize knowledge – that is, translate their research into tangible outcomes, such as informing policy change or co-creating products and tools with relevant stakeholders.

How can instructors and professors embed science communication into their teaching?

Dr. Dawn Bazely[138] incorporated editing Wikipedia biographies as a part of her undergraduate ecology course at York University[139] to both tackle the gap in representation for women in science on Wikipedia, and also provide an opportunity for students to learn how to search for reliable information online.

Dr. Robin Stoodley[140] leads "Communicating Chemistry" at the University of British Columbia, which is a required course for any student majoring in chemistry. This course teaches techniques for sharing information with other chemists, but also emphasizes communication strategies to non-scientists through written and oral presentations.

Dr. Jennifer Gardy[141] taught the "Risk and Communication in Public Health" graduate course[142] at the University of British Columbia, where students were introduced to the principles of science communication, as well as the theory and practice of risk communication in public health. This included analyzing real-world examples of successful and unsuccessful public health communication.

5.3 Public engagement must continue, but with a more inclusive lens and with structural incentives

As M.A. Lemay has stated,[143] the "promise of science" is "our expectation that science will provide solutions to intractable, complex social problems and provide socio-economic benefits that lead to prosperity. It is the driving force behind decisions to invest significant public resources in research and innovation." However, science has also often failed to live up to its promise and our expectations. The benefits of science are not always accessible to all, and sometimes only help a select subset or a privileged few.

As uncomfortable as it may be, this is a nuance that scientists must reckon with. The public's first reaction is not always to welcome science with open arms. And, in turn, the goal of public engagement and science outreach is not for everyone to pursue a degree in science, but to foster public trust and an appreciation for science.

There are several ways to foster public engagement in science and build a national science culture. Firstly, we should build on efforts to make public engagement in science fun and inclusive and bring it out to the streets. This will involve building on interest sparked by the pandemic and making science fun by embracing more interactive or unconventional models of public engagement (e.g., *Science Is a Drag* and Pint of Science). Importantly, public engagement needs to be more inclusive, such as by ensuring that languages beyond English and French are represented in engagement efforts. These models can be integrated into existing celebrations, such as Science Literacy Week, Science Rendezvous or the International Day of Girls and Women in Science.

When it comes to public engagement efforts, it is as important to focus on the processes involved in science as it is to explore new advances in science itself. In fact, at the 2021 Canadian Science Policy Conference, Dr. Mona Nemer remarked that during "peacetime," perhaps we should focus on building an understanding for the methods of science, rather than having to communicate both findings and methods during an emergency such as a pandemic.

Here are some of the incredible science communicators and their science communication initiatives across Canada

Dr. Samantha Yammine (aka Science Sam)[144] is a popular science communicator with a broad social media presence. She completed a PhD at the University of Toronto's Department of Molecular Genetics, where she investigated some of the first cells of the brain — neural stem cells. During the COVID-19 pandemic, Dr. Yammine has broken down the science behind this infectious disease, verified facts about the COVID-19 vaccines, and advocated for accommodations for people with needle and medical anxiety across her social media channels.[145]

Broad Science[146] is a podcast dedicated to making science engaging, inclusive and intersectional. It is founded by Rackeb Tesfaye, a PhD student at McGill University, who also serves as a mentor to the Chief Science Advisor's Youth Council, and is a radio science columnist on CBC's *Let's Go with Sabrina Marandola*.

Lotus STEMM[147] is a networking and leadership platform for South Asian women in science, technology, engineering, math and medicine. In particular, during the pandemic, Lotus STEMM partnered with ScienceUpFirst to fight misinformation while increasing science equity, by translating content into a variety of South Asian languages.

Science Literacy Week[148] showcases the many ways kids and families can explore and enjoy the diversity of science in Canada. Libraries, museums, science centres, schools and not-for-profits come together to highlight the books, movies, podcasts and events that share exciting stories of the science, discoveries and ingenuity shaping our lives. This annual celebration of science was first started by Jesse Hildebrand,[149] then an undergraduate student, and is now coordinated by the Natural Sciences and Engineering Research Council (NSERC).

It will also be important to build trust and partnerships with local communities. When it comes to new or ongoing research projects, communities should be appropriately consulted throughout the process, so that they can provide feedback on project scope and have ownership of the data that is collected. Individuals can also carry out science on their own through citizen or community science platforms. Generally, citizen science allows[150] non-specialists or non-scientists to conduct scientific research, directly or indirectly with scientists. Participation can range from data collection to processing results. With the evolution of mobile technologies, citizen science applications are widespread and facilitate accessible ways for individuals to do science in their own communities, such as tracking plastic pollution.[151] There are countless applications ranging from monitoring water quality[152] to tracking litter[153] that allow users to not only access their own data, but to also access data from others through open-access portals.[154] Overall, there is an increasing call for scientists at all levels to be transparent with their work and share their science through open-access platforms that do not require paywalls and engage in science communication initiatives with broader audiences.

Youth Council member Justine Ammendolia tracking plastic pollution in her neighbourhood

Tracking plastic pollution, from Newfoundland to the streets of Toronto

Justine Ammendolia: As an environmental scientist, I am interested in how humans impact the environment through their trash. As a plastic pollution researcher, I measure the types and amounts of trash across our terrestrial and aquatic environments, across both time and space. I started monitoring plastics by recording litter on the remote coastlines of Newfoundland, and my work eventually led me to the streets of Toronto.

During the start of the COVID-19 pandemic I applied my experience in tracking trash to measuring the leakage of pandemic-related items in my home city of Toronto, Ontario. Using a citizen science application, Marine Debris Tracker,[153] I tracked littered personal protective equipment (PPE) and sanitation items around my neighbourhood during different stages of the pandemic to map sources and sinks of this pollution.[155]

After developing a local method of monitoring in my area, I expanded efforts to monitor pandemic-related debris with others around the world. I collaborated with fellow researchers and citizen scientists abroad and shared my methods, so that they could monitor PPE in their own neighborhoods. This international monitoring initiative was funded by the National Geographic Society. My work with citizen scientists also extended to making a record of animal entanglements using digital and social media platforms to access posts. These pollution projects that I led were critical to understanding the impact of the pandemic on the environment as rooted through the engagement with a broader community. Much of my science communication from this work has been focused on informing the general public through media articles[156] and National Geographic outreach initiatives.[157]

I hold a Master of Science in Marine Biology (2017) and a Bachelor of Science (2014) from Memorial University of Newfoundland and the University of Guelph, respectively. I am currently a PhD student at Dalhousie University.

Too often, science communication is carried out as a "side hustle" or is undervalued as a service or a career. If we hope to truly build a national (and sustainable) science culture, we must embed a willingness to participate in public engagement and science communication, through institutional incentives. In other words, we cannot ask science communicators to work for free, or for "exposure." We must implement institutional efforts to value this niche expertise with fair compensation, whether it is being carried out by a researcher (in addition to their primary role), or by science communicators (as a full-time career). We must also take efforts to protect scientists from harassment; during the pandemic, women experts have faced vicious online hate[158] for speaking publicly about COVID-19.

As Dr. Ruth Morgan stated[159] recently, "if one million scientists (approximately 10% of the world's active science population in public service) committed two hours per week to science engagement with and for society (about 5% of their working time), this would create approximately 100 million hours/ year dedicated to achieving science that engages meaningfully with policy and global decision makers. Those hours could catalyze a global butterfly effect that could carry into the future." This vision, as lofty as it may be, is one that we hope to see realized in Canada.

The different forms of science communication: From genomics to policy, writing a children's book and more

Farah Qaiser: I'm a genomics researcher by training, now taking a detour into the world of policy. I wear many hats—all in an effort to help make a difference and build an inclusive science culture through outreach, communication and policy.

Let me explain!

I hold a Master of Science in Molecular Genetics (2020) and a Bachelor of Science (2017) from the University of Toronto. In my research, I used DNA sequencing to better understand how changes in our genetic code, such as typos (single nucleotide variants) or repeated phrases (repeat expansions), could lead to neurological disorders such as epilepsy.

But, as I trained in science, I noticed common issues pop up again and again. For example, I observed how science is jargon-heavy, often locked behind paywalls, and that scientists belonging to historically excluded communities face systemic barriers.

Youth Council member Farah Qaiser speaking on a panel

To address this, I've led different initiatives to tackle barriers to science. For example, to make science more accessible, I've written over 100 pieces about science for various media outlets (including *Forbes*). To equip scientists, especially the next generation, with the skills to participate in public engagement, I've led several science communication training programs (such as the Science Communication Toolbox for Researchers)[160] and co-founded the Toronto Science Policy Network[106] to provide a space for trainees and researchers to learn about and engage in science policy. Lastly, to change the face of science, I lead Wikipedia Edit-A-Thons to create pages about under-represented scientists, and, with neuroscientist Hajer Nakua, I will publish my first children's picture book in 2024, titled *Khadija and The Elephant Toothpaste Experiment*, which features a young Muslim girl exploring the world of science.

Today, in my role as Director of Research and Policy at Evidence for Democracy,[161] I am bridging the gap between science and policy. I've led research into the transparency of evidence usage in policy making, co-developed the Science To Policy Accelerator training program, and even testified about current challenges for science in Canada in front of the Standing Committee on Science and Research.

5.4 Calls to action: How to continue fostering the two-way relationship between science and society

1. **When it comes to writing about science, be clear, write in plain language and incorporate core principles of inclusive science communication.** This starts with understanding who our audience is and tailoring our message to them. As Stableford and Mettger state,[162] "[p]lain language embodies clear communication. While some mistakenly believe that the term means just using simple words, or worse, 'dumbing things down,' it actually refers to communications that engage and are accessible to the intended audience."

2. **Implement mechanisms to ensure that the language of science is accessible, starting from when science is produced and shared.** Here, academic journals and funding bodies (both funding agencies and third-party organizations) can incorporate, and perhaps even mandate, the inclusion of plain-language abstracts or "lay" summaries to be submitted as a part of the manuscript or grant application process. This will ensure that when research is shared publicly (e.g., in a media release or on a website), it is in fact accessible to the broader public. For example, academic journals like FACETS[163] now provide manuscript authors the option to submit a plain language abstract, and the federal department Fisheries and Oceans Canada (DFO) has mandated that all manuscripts[164] with a DFO author must produce a short plain language summary.

3. **Create and embed more science communication training opportunities in academic institutions, with an eye towards considering different career stages and training tailored for different mediums.** We call on academic departments and faculties to revisit their undergraduate and graduate curricula and examine where science communication training can be incorporated (e.g., as a mandatory course, or as a component embedded within courses). Solutions here can range from broadening

the scope of curricula for both undergraduate and graduate levels, to training senior staff and faculty in more nuanced methods for communication. We also call on teaching instructors and professors to incorporate science communication training into course assignments, and to explore the potential for more creative or innovative assignments. This can include learning about the core fundamentals of science communication and applying these concepts to different forms of public engagement, including speaking to elected representatives, giving media interviews and leading local community efforts.

4. **Build on existing efforts to make public engagement in science fun and inclusive, and help bring science out to the streets.** This will involve building on interest from the pandemic, making science fun by embracing more interactive or unconventional models of public engagement, and integrating models like these into existing celebrations, such as Science Literacy Week. Efforts should also focus on multilingual public engagement and exploring processes involved in science, and not just new advances in science. A lot of such efforts are being led by science centres and museums, as well as at the grassroots and community levels, and so ensuring that there are sustainable sources of funding available for such science promotion activities will be key.

5. **Implement institutional efforts to value and incentivize participation in science communication and public engagement.** Science communicators should be compensated for their efforts with pay, similar to a communications or marketing specialist. Institutions should recognize science communication as a component to evaluate when it comes to hiring, promotion and tenure decisions, as well as in grant applications. Lastly, awarded grants should include funds set aside to hire a communications specialist, or, in the long term, institutions should provide researchers with access to communication specialists to truly ensure that science is not locked behind paywalls or trapped within labs.

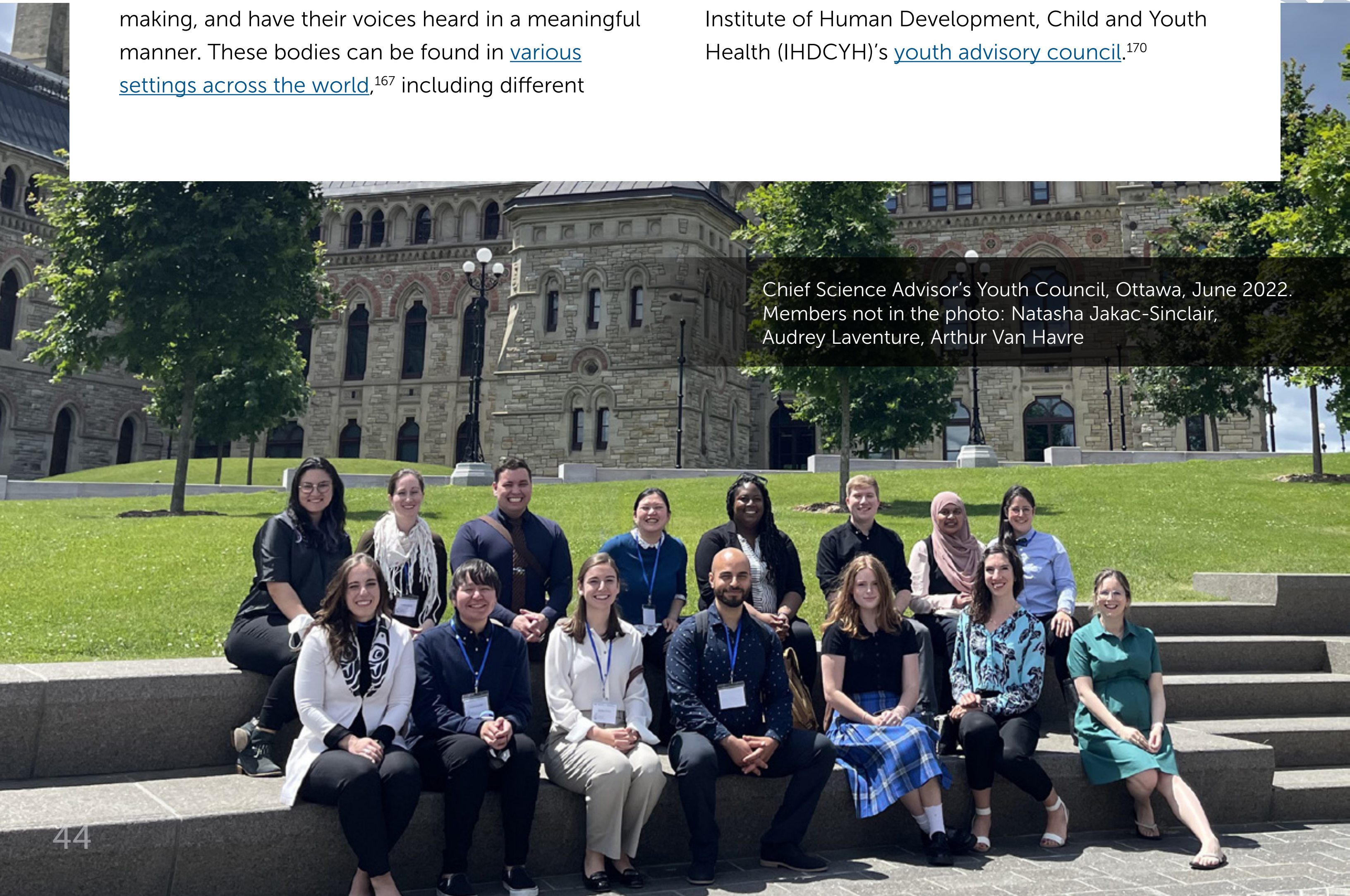
6. **Protect individuals who participate in public engagement and science communication efforts from harassment.** For example, academic institutions can support, recognize and amplify the efforts led by their employees when it comes to public engagement. Institutions should offer training in cyber-security to help prepare scientists in case harassment ever occurs, and be ready to take protective steps (e.g., temporarily hide contact information for researchers who are facing hate). Institutions should also take action to prevent the spread of disinformation by their own employees (e.g., for physicians who abuse their credentials to spread disinformation,[165] medical boards can hold these individuals accountable in accordance with existing consumer protection laws and state statutes). Lastly, while social media platforms have taken some steps to address misinformation and harassment, they can go further still by dedicating more resources towards moderation decisions (e.g., post removal, banning) and expand categories for reporting posts that involve harassment or misinformation.

6. THE NEXT GENERATION OF SCIENCE ADVICE

The United Nations' Convention on the Rights of the Child (CRC)[166] has been ratified in over 194 countries (excluding Somalia, South Sudan and the United States). Article 12 of the CRC states that "young people have the right to express their views freely and have their opinions listened to in all matters affecting them." One such way is through participation opportunities in local governance and decision making, such as youth councils.

A youth council is an entity which is consulted primarily on issues of concern to youth, and also provides an opportunity for youth to express their concerns, provide input to inform decision making, and have their voices heard in a meaningful manner. These bodies can be found in various settings across the world,[167] including different levels of governments, in non-profit organizations, or embedded into pre-existing governmental departments. They can also be referred to as youth advisory boards or commissions, and may take on derivative forms, such as youth parliaments. What makes youth councils unique is their connection to decision making, such as how we, the Chief Science Advisor's Youth Council, provide input and advice to Dr. Mona Nemer and her office.

Today, a number of youth-led bodies, student-run science policy groups and federal youth councils exist, such as the Science and Policy Exchange,[168] the Prime Minister's Youth Council,[169] and the CIHR Institute of Human Development, Child and Youth Health (IHDCYH)'s youth advisory council.[170]



Chief Science Advisor's Youth Council, Ottawa, June 2022.
Members not in the photo: Natasha Jakac-Sinclair, Audrey Laventure, Arthur Van Havre

Including the next generation in science advice and decision making:
***Le Comité intersectoriel étudiant* (Intersectoral Student Committee)**

Created in 2014, the Intersectoral Student Committee (Comité intersectoriel étudiant or CIE)[171] was originally Québec's Chief Scientist's own student advisory committee. Since then, it has become a statutory committee of the Fonds de recherche du Québec (FRQ), i.e., Quebec's provincial research funding agencies (health sciences, social sciences and humanities, natural sciences and technology). The CIE's mandate is to advise the Chief Scientist and the three FRQ boards of directors by identifying strategies to improve the funding and accessibility of graduate studies, better support the different forms of research excellence, and promote student-driven research.

The CIE brings together CEGEP-level, undergraduate, Master's, and PhD students, as well as postdoctoral researchers, from across academic disciplines and training environments. Over the years, the CIE has proven its essential role within the FRQ and Quebec's research ecosystem, namely by undertaking extensive reflections that led the FRQ to update their scholarship programs and to create new ones (e.g., postdoctoral scientific residencies[172] within Quebec's international offices).

Now a statutory committee, the CIE is an integral part of the FRQ's governance structure. Most importantly, a different CIE member serves on each of the funding agency boards. This directly involves the next generation in strategy development and decisions related to the funding and training of researchers. Youth council member **Madison Rilling** was vice-president of the CIE from 2016 to 2019 and also served as an FRQ board member.

6.1 Reflections on youth participation

As heart-warming as this progress is in the increasing avenues for youth participation, there are a number of challenges and limitations involved in youth participation. For example, an open-ended survey of youth and adults involved in 32 different youth councils across Canada[173] found that while a majority of past participants felt that their voices were heard through youth councils, their successes were not without challenges, including limited adult support, varying commitment levels among the young people, having to address tokenism and bureaucracy, managing busy schedules, and facing difficulties in recruiting young people belonging to historically excluded communities, such as young people who are homeless.

Likewise, we, as members of the Chief Science Advisor's Youth Council, have faced these growing pains too, no doubt further complicated by the fact that our council was launched amid a pandemic. As a nation-wide council composed of young people in typically transitional periods in our lives, we have also seen challenges with managing changing schedules and priorities — especially as COVID-19 impacted the pace at which information and data was being produced in all aspects of science.

There is also limited empirical research[167] on how, and to what extent, youth participation can make contributions to policy. Within youth councils, emphasis tends to be on individual-level development and educational benefits for youth, rather than the practical value or impact of their contribution to decision making.

Toronto Science Policy Network

In 2018, a group of graduate students at the University of Toronto, including **Molly Sung** and **Farah Qaiser**, co-founded the Toronto Science Policy Network,[106] a student-run science policy group. Our aim was to create a space for trainees and researchers to learn about and engage in science policy, through workshops, panels and campaigns.

Our efforts demonstrate how trainees can play a critical role in science advocacy and policy, and offer critical insights into decision making. For example, in 2019, we were one of the leading organizers behind the Vote Science campaign,[174] a non-partisan effort to advocate for science in the federal elections. Our efforts led to over 600 Canadians sending an email to their local federal candidates, and signalling their support for science.

In 2021, we led a COVID-19 Graduate Student Survey,[5] where we were one of the first to survey, and hear directly from, over 1,400 graduate students across Canada, and understand the early impacts of the COVD-19 pandemic. We heard how COVID-19 impacted the ability of graduate students to conduct research, widespread concerns about financial stability and mental health, and uncertainty about the ability to graduate because of changes resulting from COVID-19. As a result, we put forward a number of recommendations to better support graduate students across Canada.

Today, the Toronto Science Policy Network lives on, and it has inspired the creation of more student-run science policy groups across Canada, including the Ottawa Science Policy Network.[175] We hope to see more student-run science policy groups in the future!

6.2 Opportunities in science advice for the next generation

The COVID-19 pandemic has led to increased interest from trainees and early career professionals[176] to explore the world of science policy and advice, especially as scientists and their contributions to the policymaking process have been placed at the forefront of the crisis. We must continue engaging and amplifying the voices of the next generation in policy, not only for capacity building, but also to ensure that we are better prepared for the next set of challenges.

The ways in which this can be achieved are to be open and mindful to the contributions of multiple sectors of society in solving these challenges. The next generation of science should be encouraged to explore how solutions to challenges can be implemented by recognizing the role of other disciplines such as regulations, economics, finance and logistics. Understanding how one's primary field of study is situated within society and the economy can only be achieved through interdisciplinary collaboration. Well-rounded participation will be the key to the next generation of scientists.

But when inviting members of the next generation of scientists and workers to the decision-making table, we must do more to ensure genuine inclusion where their priorities are meaningfully considered, rather than turn youth engagement into a box-checking exercise. Youth are often portrayed as idealistic and unrealistic in their visions of a better future—but we would argue that these traits are exactly why youth perspectives are critical and should be provided a seat at the table. An ardent belief that a better future is always possible and worth striving for is our greatest strength, and is the best way to guard against complacency.

6.3 Calls to action: How to incorporate the voices of the next generation in decision making

1. **Create and embed youth councils (or other forms of youth participation) across academic institutions and levels of governments.** For example, councils can be created in research settings, such as the Human Environments Analysis Laboratory Youth Advisory Council (HEALYAC).[177] Fortunately, creating a youth council from scratch is not an arduous task, especially as there are many rich, descriptive case studies and available guides[178] and toolkits.[179]

2. **Work towards ensuring genuine inclusion of youth voices and perspectives in decision-making spaces.** Youth councils should not replace other forms of consultation, including surveys, youth organizing, youth forums, youth participatory research or exploring different structures (such as having a dedicated seat on the organization's board of directors for youth or an early career professional). In some cases, it may not be a question of creating a new youth body, but ensuring representation or better integration of youth into existing bodies or decision making spaces. As always, it is important to consult with communities directly, and co-create spaces or structures to ensure that young people are able to participate, in ways that are comfortable and accessible to them.

7. CONCLUSION

As members of the Chief Science Advisor's Youth Council, we have watched as the world attempted to navigate large nuanced issues, such as the COVID-19 pandemic, climate change, systemic racism and political strife. We see how all of these issues are linked and interact with science, both domestically and abroad. And while we acknowledge that we still have much to learn, we also know that we have much to contribute.

We hope that the calls to action outlined in this document will serve as a launching point for building a science culture that is more inclusive, collaborative, open, interdisciplinary and reflective, and that these shifts positively influence all aspects of life in Canada. This necessary work will not be done overnight, nor can we do it alone – and importantly, dear reader, we will need your voice and participation as we strive to make science better for everyone, today and in the future.

8. CONTRIBUTING AUTHORS

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