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Opinion Article

Teaching scientific evidence and critical thinking for policy making

Natalia Pasternak Taschner [1,2,*], Paulo Almeida [2,3]

[1]Center for Science and Society, Columbia University, New York, NY, United States
[2]Instituto Questão de Ciência, São Paulo, Brazil
[3]School of Economics, Business and Accounting, University of São Paulo (FEA USP), São Paulo, Brazil

*Correspondence address. Center for Science and Society, Columbia University, 511 Fayerweather Hall, 1180 Amsterdam Avenue New York, NY 10027, United States. Tel: (212) 854-0666; E-mail: np2804@columbia.edu

Abstract

While there is worldwide tendency to promote the use of scientific evidence to inform policy making, little has been done to train scientists and policy makers for this interaction. If we want to bridge the gap between academia, scientific knowledge, and policy, we must begin by providing formal training and skill building for actors and stakeholders. Scientists are not trained to communicate and inform policy, and policy makers are not trained to understand scientific process and assess evidence. Building an environment where this collaboration can flourish depends on teaching competencies and abilities specific for decision-making processes. As professors of policy with a background in science, we have started teaching preliminary courses on the use of scientific evidence in policy making. Feedback from students and institutions has been positive, paving the way for similar courses in other schools and institutions and maybe even new career paths. This article is intended to share our experience in designing and teaching courses aimed at training policy makers. Moving forward we plan to include training for science majors, thus encompassing the two main sides of this dialogue and opening new career opportunities for scientists and policy makers.

Keywords: critical thinking; science-based policy; science advice; policy making; scientific evidence; teaching

Introduction

Science advice is in high demand. However, it is also under constant scrutiny and scientific evidence itself has been often contested [1]. If we consider themes that are viewed as controversial by the layperson, the problem can get even worse. Even before the coronavirus disease 2019 (Covid-19) pandemic, topics like climate change, vaccine safety, Darwinian evolution, genetic modification, and food biotechnology were already difficult topics to navigate. If a private citizen is already confused when making decisions about vaccination or the preferred use of energy sources, the policy maker faces a more difficult challenge: the decision has to be backed by evidence, and the policy maker has to be able to sort between solid scientific evidence and noise.

With this in mind, we propose that training scientists in how to provide science advice and policy makers in how to use scientific evidence is urgent and necessary. Scientists are not regularly trained to talk to policy makers, government officials and parliament members. Likewise, decision makers in general are not regularly trained in the understanding of science and the use of scientific evidence to inform policy. Providing training for both scientists and policy makers can help get this conversation started and guarantee that science is contemplated as a tool in the decision-making process.

Science for policy

The use of scientific evidence to inform public policies is not new. Neither is the need of science literacy and science understanding for decision making. The European Commission, back in 1995, already stressed the importance of science literacy as a tool for a democratic society, as highlighted by the Science Literacy report of the National Academies of Sciences [2].

> *Democracy functions by majority decision on major issues which, because of their complexity, require an increasing amount of background knowledge. For example, environmental and ethical issues cannot be the subject of informed debate unless young people possess certain scientific awareness. At the moment, decisions in this area are all too often based on subjective and emotional criteria, the majority lacking the general knowledge to make an informed choice. Clearly this does not mean turning everyone into a scientific expert, but enabling them to fulfill an enlightened role in making choices which affect their environment and to understand in broad terms the social implications of debates between experts.*

Addressing this issue includes building understanding and also training people to work at this interface, be it training scientists in policy making or policy makers to understand the use of science. The Organization for Economic Development and Cooperation defines scientific literacy as the ability to "research, evaluate and use scientific information to make decisions and actions" [3].

Understanding science requires a minimum background knowledge of how science works, but it does not require a formal background education in science, in the sense of having attended science or medical/health schools. It's about science literacy, not about becoming a scientist. Unfortunately, policy makers across

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the world are ill prepared in science literacy. Health emergencies like the Covid-19 pandemic forced us to realize that there is urgent need for science literacy, science communication and risk communication, and the ability to sort between science and noise, and of knowing where to look for solid science-based information.

Some authors have tried to improve the use of evidence in health [4], other have tried to increase the transfer of knowledge from research to decision makers [5]. Some countries have even implemented government sponsored strategies for the use of scientific knowledge for policy, such as the UK "What works centre" [6], and the "Health in the city program," in the Netherlands [7]. In the USA, the issue has been addressed by authors who have highlighted the frustration of researchers when science is ignored or misused to inform policies [8].

Internationally there have also been attempt to highlight the need for official bodies of scientific advisory [9], and to address the difficulties of the model created by the presence of a chief scientific advisor (CSA), where the CSA is chosen for their personal achievements and credibility and are not particularly trained for the position [10]. One example is the report by the UK Science and Technology Committee citing as one of the essential skills of a CSA: "standing and authority within the scientific community" [11]. Pielke and Klein have stated that we should not regard the CSA as a lone hero with access to all the answers, while at the same time being able to protect science from political influences [12].

What knowledge do policymakers need about science? What knowledge do scientists need about policy?

Peter Gluckman [9] brings what he considers to be the top ten principles for a CSA: maintain the trust of the many, protect the independence of the advice, report to the top, distinguish science for policy from policy for science, expect to inform policy, not make it, give science privilege as an input into policy, recognize the limits of science, engage the scientific community and the policy community, and act as a broker not an advocate. We try to incorportate Gluckman's principles in the skills we build with our students in class. We discuss the importance of science diplomacy for international collaboration, for instance, but we also discuss the need for scientific consensus reports like IPCC, which can act as an "honest broker" in providing the evidence to inform policy, without advocating for a cause. Recognizing the limits of science and being able to communicate uncertainty are also part of our lessons, and we do a deep dive of the literature on science and risk communication.

Likewise, Paul Cairney and Kathryn Oliver argue that advice to academics on how to impact policymaking is mainly vague and superficial, emphasizing that we need science advisors skilled in writing reports that are short, concise, available in plain language, avoiding the usual jargon found in peer-reviewed articles [13].

It seems unlikely that anyone can learn how to navigate these principles just by having a background in science and being on the top of their academic fields. Excellence in the sciences is not sufficient to be a good intermediate between science and policy, the position requires training.

The use of science to inform policy raises many challenges, and with the speed of scientific discoveries, and the amount of information and disinformation available online, where does the policy maker stand? We need policy makers who are trained in scientific literacy, even if they don't have a background in science. We don't expect them to become experts, but rather to be able to navigate through misinformation and disinformation, assess different levels of evidence, identify experts, and use science as one of the many tools in the policy maker's decision-making process. On the other hand, we also need scientists trained in policy making, who can understand governance structures, law and regulation processes, and above all, who are able to communicate science effectively.

In practice, teaching scientific literacy is not that simple. If, on the one hand, we have studies that point out the importance of understanding science so as not to be deceived by misinformation [14, 15], there are also others that show that providing science-based information is not enough, as unwarranted beliefs can be motivated by political and ideological biases, the feeling of belonging to this or that particular group, as well and cultural and historical values [16–18]. The need, therefore, to develop effective systems to teach people to think rationally and critically, and to develop scientific thinking as a decision-making tool, regardless of their background, and chosen professional career, is a reality.

Schmaltz and Lilienfeld suggested in 2014 the use of pseudosciences as a tool to teach scientific thinking in higher education [14]. The authors argued that with the increase in misinformation, teaching psychology majors to differentiate science from nonsense was essential. Using examples of unwarranted practices and beliefs, the authors taught about logical fallacies and mind traps that make many pseudoscientific practices seem to work.

Fasce and Picó investigated the use of scientific literacy as a vaccine against pseudoscience, or more precisely, what they called unwarranted beliefs, including pseudoscientific beliefs, belief in the paranormal, and belief in conspiracy theories [19]. They found correlations between scientific knowledge and trust in science as predictors of beliefs in pseudoscience and the paranormal, but not in conspiracy theories, where the correlation was much weaker. A similar result was obtained by Dyer and Hall, but with very promising results for the teaching of scientific literacy and critical thinking: the researchers carried out a randomized controlled test for the teaching of critical thinking as a predictor of the reduction in unwarranted beliefs [15]. California State University undergraduate students were divided into three groups. One group participated in Dyer and Hall's course on science and pseudoscience, where the professors directly addressed examples of popular pseudosciences such as astrology, homeopathy, UFOs, Big Foot, etc., and the other two groups attended regular scientific methodology courses. Questionnaires were administered before and after the courses, and the results showed that the students who attended the specific science and pseudoscience course had a significant reduction in unwarranted beliefs, compared to the ones who took the regular courses, where no difference was visible. Beliefs in conspiracy theories were the one criterion where the effect was not as significant, but there was a drop nonetheless. The authors conclude that the educational strategy of addressing pseudosciences directly is the most effective in changing beliefs, and promoting scientific literacy that translates to everyday life choices [15].

On the other hand, if teaching science to policy makers is not that simple, the reverse is also difficult. Scientists who engage in policy should learn about governance, laws, and regulation, understand how the process of policymaking works, and what role is expected of a science adviser. The report delivered by the International Science Council and the International Network for Government Science Advice [20], outlines the two main components of science advice as evidence synthesis and knowledge brokerage. They explain that these set of skills encompass the ability to establish the state of the best evidence available in a concise and precise manner, while acting as a broker not an advocate. Brokerage is thus defined as the ability to bring scientific evidence by helping policy and decision makers to understand scientific information. Brokers can be defined as interpreters between parties who do not necessarily understand each other [21].

Perhaps the most accurate description of what set of skills are needed for science advisers was given by Haynes *et al*. [4], after conducting a set of interviews with civil servants in Australia about what they consider to be the most important competencies and abilities in a science advisor. Policy makers in general came up with the following list: "competence (an exemplary academic reputation complemented by pragmatism, understanding of government processes, and effective collaboration and communication skills); integrity (independence, 'authenticity', and faithful reporting of research); and benevolence (commitment to the policy reform agenda)" [4]. Some examples given by the authors include the need for experts capable of moving away from pure research and into the "messy real world," able to communicate in a plain language and without jargon, being trustworthy and independent, and being transparent. Another aspect pertinent to this discussion that appeared in the interviews and seemed to be a consensus among the civil servants was that although they highly valued academic achievement, they all prefer to work with scientist that understand government processes, bureaucracy, public health infrastructure, and parliamentary processes [4].

Our courses

Bearing in mind the need to train both scientists and policy makers with a new set of skills to enable both sides of the conversation to understand each other, we initially designed three courses tailored to train policy makers in understanding scientific evidence. Two courses are currently being taught at the Public Administration School at Fundação Getúlio Vargas in Sao Paulo, Brazil. "The use of scientific evidence in decision-making processes" is an undergraduate elective offered to students majoring in Public Administration, International Relations, and Law, and the "Science Diplomacy" course is offered to Graduate Students, in the master's Program in Public Administration. The third course is offered at Columbia University, in the Executive Master of Public Administration program at School of International and Public Affairs and is called "The Use of Science-Based Evidence in Decision and Policy Making." This is co-taught by one of the authors (Natalia Pasternak). More recently, in Spring 2024, Pasternak also started to offer another undergraduate course at Barnard College, in the Science and Policy minor. The course is called Science-based evidence in policy making. A summarized version of the syllabi to the courses is available as supplementary material (Supplementary material).

In all these courses, our main concern was to provide the students with tools to improve their science understanding and scientific literacy and make better choices and recommendations in their future or current jobs, while at the same time being able to communicate effectively and with transparence about the limitations of the evidence. The Science Diplomacy course also covers international collaboration and the use of evidence for global challenges. The aim of the courses was never to present science as the only solution, or the only knowledge necessary for decision making, but as one tool that can be useful to future policy makers. In accordance with the role of science advisers as brokers, and with giving science a privileged place in the decision-making process [9] we believe that science should inform policy, not dictate it. Content in all three courses includes basic notions of philosophy of science, clinical trials, cognitive biases, logical fallacies, different approaches for citizen participation in decision-making, and case studies of government decisions that ignored science, and their consequences.

To cite a few examples, one of the case studies is the history of HIV denialism in South Africa and its consequences. To explore the consequences of not heeding medical advice in public policy students learn the case of how the South African government handled the HIV/AIDS crisis in the 1990s–2000s. During the AIDS pandemic, South Africa suffered from misinformation and disinformation about HIV coming directly from President Thabo Mbeki, who in 1999, spoke against the use of antiretrovirals, stating that they were toxic and dangerous to health [22]. He questioned the causal link between HIV and AIDS and refused to promote awareness campaigns and to establish health policies for treatment with tested, globally accepted medications. He appointed a council of advisors that, quite deliberately, included AIDS dissidents. South Africa was so severely affected by the AIDS pandemic that more than a decade late the country still has one of the largest HIV-positive populations in the world. According to estimates from the United Nations, approximately 18.8% of the adult population is infected with HIV. This is nearly 5.5 million people. AIDS denialism led to lack of proper public policies, which led to a higher number of deaths when compared to countries in similar situations. Chigwedere *et al*. [22] used mathematical modeling to compare the use of antiretroviral drugs in Botswana and Namibia, countries with populations similar to South Africa. They concluded that more than 330,000 lives were lost because antiretroviral programs were not implemented in South Africa. Approximately 35,000 babies were born with HIV, something that could have been prevented by a mother-to-child prophylaxis program. And this is just direct damage, measured between 2000 and 2005. South Africa still suffers from AIDS denialism, and this could even have been a source of vaccine hesitancy during the Covid-19 pandemic.

We discuss the impact of the HIV/AIDS denialism and what cultural and historical factors might have contributed to the escalation of the situation in South Africa. While comparing South Africa to the neighboring countries, we try to identify what particular factors are present in the South African society that are not present in other countries? The students usually bring up the fact that the very history of apartheid might have led to a natural suspicion of anything that comes from the West, including western medicine, making it easier for the denialist ideas to spread, and for South Africans to fall for conspiracy theories involving the HIV/AIDS medications. A comparison to the recent Covid-19 pandemic is inevitable, and we discuss how we can learn from the South African experience, how similar situations emerged where minority communities in the US rejected Covid vaccines due to trust issues and conspiracy beliefs, and how this could have been prevented.

Another example we use in class is Sri Lanka's government decision to turn all agricultural practice in the country 100% organic in 2022 [23]. In an exploration of policy decisions based on ideology rather than scientific evidence the students explore how Sri Lankan President Gotabaya Rajapaksa imposed a nationwide ban on the importation and use of synthetic fertilizers and pesticides and decreed that the whole country shifted from conventional agricultural practices to organic only. This was not based on the best science available, but on politics and ideology, and the result was disastrous. A country that has always been self-sufficient in rice production suddenly had to import, and saw its major export product, tea, lose yield and affect the economy and foreign exchange.

The students explore the decision-making process that led to the ban, how the President chose what experts to consult, who were the experts and agriculture scientists excluded from the conversation, and the economic crisis that followed, eventually forcing the country to review the ban. We compare the Sri Lanka situation to the strong lobby in other countries to adopt a 100% organic agriculture, and to the long history of the European Union strict regulations on genetic modification and gene editing. Food biotechnology and organic agriculture are important topics to cover and give us the opportunity to discuss how much of the decision-making process in these cases really take science into account, and the importance of considering how people feel. We analyze literature about science communication and understanding of genetics, and students realize that most people overestimate what they really know about these topics [24].

These are examples of what happens when science is ignored in policy. Besides the case studies, our syllabi encompass class meetings on disinformation pipeline and how it affects trust in science and public institutions [25], what really works to increase vaccine uptake and reduce vaccine hesitancy [26], how to communicate about risk [27], and how to communicate scientific evidence [28]. We also dedicate some classes to discuss cognitive biases and beliefs, evidence-based solutions and how randomized trials can be used in social sciences [29, 30]. Students are evaluated by their participation in class, and must write a policy brief, a short document making a recommendation based on scientific information. The use of the policy brief is in accordance with the recommended skill of being able to provide evidence in a concise, clear way, and being able to translate scientific evidence into plain language [4]. Examples of policy briefs were included as supplementary material (Supplementary material).

And finally, by the end of the course, students from some courses participate in a mock debate about a "controversial" scientific topic. Past topics included food biotechnology and genetic modification, the use of embryonic stem cells in research, and vaccine hesitancy. Students are divided into two groups: the "pro-science" and the "anti-science." The idea is for the students in the anti-science group to use logical fallacies, distortions of science, and ideological arguments, and the "pro-science" group should be able to recognize those fallacies and denialist arguments and counterargue. The mock debate is a fun activity, designed for the students to experiment how hard it is to present and defend scientific evidence in the real world, surrounded by noise and disinformation. These are real life situations where it will be necessary to act as a knowledge broker, separating science from noise without disregarding people's feelings, cultural background, and political and social context.

Moving forward

Although we have been teaching all courses for a short period, feedback from students and institutions has been positive, except from the Barnard College course which is currently being taught for the first time this Spring. So far, students frequently note that they feel more prepared to engage in a conversation about science, and how to look for evidence. They know how to find the best experts, and how to read and interpret a scientific paper and a press release. They feel more confident about their ability to spot false claims and misconceptions, and to see red flags on websites and people trying to promote misinformation and disinformation. Some of the students' informal feedback are quite rewarding to us as teachers, such as the student who said "I feel so much smarter now, like no one can fool me," or another who worked as a government officer for the Ministry of Agriculture in their country, and told us that after taking our class and learning about organic agriculture, he understood the limitations of the method and was going to recommend against the agenda to go 100% organic. We had students who were really surprised to find out that some alternative medicine practices were not backed by science, and that the methodology for randomized clinical trials could be used to test social interventions. They also mentioned the importance of developing metrics and how they realized that most public policies don't have follow-up metrics, and nobody knows if they really work. In general, they all say they fell more prepared to search, understand and communicate about scientific evidence.

Moving forward we want to focus on training scientists as well as policy makers. Bringing science majors into policy could even lead to a new career path for science graduates who do not wish to pursue academic careers but would like to use their knowledge to contribute to society. A career in policy usually values basic knowledge in economics, law, and public administration, but science is off the radar. Scientists don't usually see a career in policy as a possibility. We wish to change this. After all, having a science background includes knowledge in critical thinking, data analysis, and assessing evidence, all of which are important skills for policy making. Building a dialogue between science and policy makers, where the actors and stakeholders involved can actually speak the same language requires training, and specific skills. And it requires diverse and interdisciplinary faculty members, and collaboration among different schools. From our brief experience teaching the use of science-based evidence to policy makers, we believe that there is room to improve and expand the training and to open new job and career opportunities.

Author contributions

Natalia Pasternak Taschner (Conceptualization [lead], Writing—original draft [lead]) and Paulo Almeida (Writing—review & editing [equal])

Supplementary data

Supplementary data are available at *Biology Methods and Protocols* online.

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