Opinion

The need to build policy literacy into climate science education

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An increased focus on 'policy literacy' for climate scientists, parallel to 'science literacy' for the public, is a critical need in closing the science–society gap in addressing climate mitigation. We define policy literacy as the knowledge and understanding of societal and decision-making contexts required for conducting and communicating scientific research in ways that contribute to societal well-being. We argue that current graduate education for climate scientists falls short in providing policy literacy. We identify resources and propose approaches to remedy this, arguing that policy literacy education needs to be mainstreamed into climate science curricula. Based on our experience training science students in global environmental policy, we propose that policy literacy modules be developed for application in climate science curricula, including simulations, case studies, or hands-on policy experiences. The most effective policy literacy modules on climate change will be hands-on, comprehensive, and embedded into scientific education.

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INTRODUCTION

Leading scientific organizations, including the U.S. National Academies and the American Association for the Advancement of Science (AAAS), have argued that science should play a key role in addressing major societal challenges such as climate change.[1] Scientists need more than simply disciplinary training to address climate change: they also need to better understand the economic, social, and political elements of the issue, and communicate more effectively with policy-makers and the general public. Both academic literature and popular media have identified a growing divide between science and society, especially on climate issues.[2]

Recently, much discussion in the literature has focused on the need for improving climate science advice to policy-makers,[3] better understanding the social and political aspects of climate science,[4] and communicating climate science to public audiences.[5] However, less attention has been paid to climate scientists themselves, and specifically their preparation for, experience in, and effectiveness at understanding and engaging in the policy processes addressing climate change. This is despite the fact that thousands of scientists engage in policy-relevant work through the Intergovernmental Panel on Climate Change (IPCC) and other assessment efforts worldwide, and that climate scientists are working in a context of an increasing politicization of climate change more broadly.[6]

Here, we advance the concept of 'policy literacy' for climate scientists as parallel to 'science literacy' for the public, and establish it as a critical need in closing the science-society gap when it comes to addressing climate change. We argue that climate

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science education at universities falls short in providing policy literacy. Based on our experience training science students in environmental policy, we propose that policy literacy training be mainstreamed into graduate climate science courses. Curricular modules that teach policy literacy could include case studies, role-play simulations, and policy experiences. To be effective, those modules should be hands-on, comprehensive, and embedded into existing courses.

The Need for 'Policy Literacy' for Climate Scientists

Science literacy is defined as 'the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.'[7] While science literacy efforts initially focused on a perceived public deficit in scientific knowledge,[8] researchers increasingly recognize that improving the science–society dialogue also requires changes in scientists' education.[9,10] While policy literacy is often mentioned in science-policy discussions, this concept has not been well-defined or developed in the literature.

We define policy literacy here, parallel to science literacy, as the knowledge and understanding of societal and decision-making contexts required for conducting and communicating scientific research in ways that contribute to societal well-being. We view this skill as part of scientists' professional training, and therefore, believe it should develop during their postsecondary science education. Policy literate climate scientists should be able to conduct research taking into account local knowledge and perspectives, manage interactions and negotiations at the science–policy interface, and communicate effectively with decision-makers and the public. As Table 1 illustrates, policy literacy has several components, including an understanding of societal needs and relevant efforts to address them. We focus on policy, as opposed to public communication more generally, because of the unique nature of the climate change issue as a topic requiring collective decision-making, and the contentious nature of discussions about potential solutions. Present and future climate scientists will conduct their work in political and policy contexts.[6]

Developing policy literacy among climate scientists has at least four main benefits. First, policy literacy helps climate scientists communicate more effectively with policy-makers and the public. Research suggests the majority of scientists engage with media,[11] but that they often confuse their audiences by using complex language or failing to put new findings in context.[12,13] As the extensive literature on risk illustrates, communication is best envisioned as a two-way process, involving mutual education.[14] More effective communication could help both climate scientists and the public better understand climate risks. Recent calls for more strategic approaches to scientists' communication training[15] could help climate scientists more clearly identify and articulate the policy relevance of their work.

Second, policy literacy helps climate scientists participate more effectively in public and regulatory discussions on both mitigation and adaptation. Climate scientists who understand the institutional context and interests that shape international policy discussions, for example, the Paris Agreement, might be better able to design and conduct research that can inform policy strategies to meet the global goals. Similarly, understanding that scientific assessments become influential based not just on scientific credibility but also policy salience and political legitimacy can help scientists participate more effectively in government science-panels such as the IPCC.[16] Climate

TABLE 1 | Examples of Policy Literacy Components and Related Learning Goals

Policy Literacy Components	Example	Learning Goals
Societal needs	Projections of climate using useful metrics, at appropriate scales	• Understand the ways in which societies rely on climate services • Evaluate the impacts of climate change on societal well-being
Local knowledge	Context-based knowledge, such as aboriginal observations about climate-driven changes in wildlife populations	• Explain the similarities and differences between types of knowledge and ways of knowing • Combine data and insights on climate variability and change from different sources
Policy decisions	Relevant decisions, such as Paris Agreement commitments and implementation strategies.	• Identify major domestic regulations and international agreements affecting climate change • Design and appraise policy options for climate change mitigation and adaptation

scientists engaging in policy discourse have also increasingly been called upon to defend their work from political and legal challenges, in forums with norms very different from those of the scientific community. Increased policy literacy may prepare more future scientists to face these types of challenges.

Third, policy-literate scientists can conduct research that is more useful for society, addressing pressing human and ecological challenges as the climate changes.[1] For example, climate scientists who understand energy policy can better capture anthropogenic driving forces behind climate change in projections. Those who understand the process by which countries are implementing their Paris Agreement targets can incorporate more realistic and useful scenarios in climate modeling and impacts analyses. Indeed, climate scientists with policy literacy skills are already doing this.

Fourth, increased policy literacy knowledge can help the professional and career development of climate scientists. Skills gained in understanding the social context of scientific work can help scientists build connections outside their discipline, which can help facilitate the cross-disciplinary research and innovation needed to address complex scientific challenges in the climate field. Policy knowledge as well as presentation and communication skills can be especially useful for early career scientists, as they embark upon careers both within and outside of academic science. A focus on societal relevance could also draw broader student interest in climate science topics, which may increase the reach and diversity of climate science and other geoscience disciplines.

Existing Science Education Neglects Policy Literacy

While it is difficult to quantify, available evidence suggests that many climate scientists lack policy literacy. Scientific communication research shows scientists often fail to explain findings in a way the general public understands.[12] AAAS notes that 'scientists often lack the skills and opportunity to apply their science successfully to support policy or to communicate effectively with the public and other non-academic audiences.'[17] While most scientists think they should communicate their work's societal implications to the public, less than half of scientists in one survey felt they were the best equipped group to communicate.[18]

Efforts exist to improve policy literacy, but they are not sufficient to address the full scope of the problem. Several organizations provide opportunities for scientists to work in policy-related positions, notably the U.S. AAAS Science and Technology Policy Fellowships[17] and professional societies' fellowships, such as the American Physical Society's Congressional Science Fellowships and the UK Royal Society's MP-scientist pairing scheme. The new Leshner Leadership Institute for Public Engagement with Science at AAAS selected a cohort of climate scientists for a year-long fellowship in which they will develop and implement public engagement activities, and increase their capacity for public engagement leadership. One of the authors of this paper (NES) is a member of this cohort. However, these programs are not broadly accessible or tailored to the classroom or lab, where most climate science training occurs. Further, these efforts typically occur as advanced training. Ideally, students could have exposure to the policy process before they begin their careers.

Specialized programs offer degrees or certificates focused on science–society interactions, and many incorporate climate and environmentally relevant science-policy training. Graduate degrees are offered by, among others, Carnegie Mellon's Engineering and Public Policy department and the Massachusetts Institute of Technology's Technology and Policy Program in the USA, as well as a number of European universities such as Delft University of Technology and Cambridge University. Postgraduate certificates or minor programs in science and policy include the University of Michigan's Science, Technology and Public Policy, and Princeton University's Science, Technology and Environmental Policy programs. There are also nondegree seminars, such as the American Meteorological Society's (AMS) Summer Policy Colloquium. While these programs help create a population of policy-literate scientists, they only serve those already interested in policy, rather than the general science student population. Thus, most science students will not receive policy literacy training through these channels.

Some science programs have distribution requirements that encourage students to take policy courses.[19] The AMS Policy Program is developing a curriculum targeted at faculty and departments integrating policy issues into science classes. The AAAS Center for Public Engagement with Science and Technology also has communication materials online, which could be adapted for classrooms. Requiring a separate course, however, does not emphasize the value of considering policy literacy within a science context. Many resources and texts also focus on 'science-policy' more narrowly defined: the relationship between government funding and scientific research, as opposed to the broader concept of policy literacy outlined here.

What is Needed to Improve Policy Literacy among Climate Science Students?

Policy literacy education should be mainstreamed into graduate-level climate science curricula. Policy literacy education needs to reach a large number of practicing climate scientists, and reinforce the idea that policy literacy is key to doing climate science better. At the graduate level, effective educational materials should be designed specifically for climate science courses. That is, we argue that policy literacy can and should be taught alongside and as a complement to climate science concepts. This is consistent with increasing calls for more interdisciplinary, problem-focused education.[20–22]

Like all process-based knowledge, policy literacy is best acquired through experiential learning. This is consistent with science education research that shows students learn most effectively through active participation.[23] Case studies have long been used in policy training courses to teach students about key concepts and value-laden tradeoffs.[24] However, few existing policy case studies address how scientific knowledge is used in decision-making.[24] Recently, new case studies have been developed to help students learn to integrate natural and social science knowledge and apply it to address environmental problems.[25] Role-play simulations, where students assume roles and then negotiate over a shared problem, are used extensively in negotiations courses. Strong pedagogical theory in negotiations supports the idea that learning-by-doing is critical in areas that require practitioners to integrate, synthesize, and communicate information.[26] As the boundaries between science and policy are often subject to negotiation,[27] scientists would benefit from learning negotiation and management skills. Simulations can also, concurrently, teach scientific concepts in an active way.

A few simulations geared toward science-policy already exist on various aspects of climate change.[28] We developed a role-play simulation called 'The Mercury Game' (http://mit.edu/mercurygame), which teaches science students about science-policy interactions in environmental treaty-making, and found that the simulation improves students' science and policy knowledge. The Mercury Game, and several other negotiation simulations like it, have been used in numerous college and graduate level courses around the world. Evaluation of 'The Mercury Game' showed that science students learned how politics and economics affect environmental negotiations.[29]

Apart from in-class activities, students could benefit from hands-on policy experiences that allow them to engage directly with decision-makers and the public. For example, many faculty members incorporated activities related to the 2015 climate negotiations at COP-21 into their courses, and several science students participated in the negotiations as members of delegations or as observers.[30] In this way, they were practicing policy literacy: improving their understanding of societal and decision-making contexts. Similarly, assignments that require students to use social media, such as blogs or Twitter, can encourage students to consider public knowledge and communication while working on scientific problems.

In addition to the pedagogical basis for teaching policy literacy in modules that include case studies and simulations, this approach also has practical advantages. A substantial barrier to mainstreaming policy literacy education in climate science classes is that most science faculty who teach these courses have little training in public policy. Modules offer educators prepackaged activities to support learning goals, often with accompanying instructor guides. These activities can be easily integrated into climate science curricula, without sacrificing the topics covered and using materials increasingly available online.[23,31] It would be useful to develop a repository of policy literacy modules suitable for science students. A good example of what this could look like is the 'On the Cutting Edge' project in the geosciences, which includes numerous teaching resources on coupled human–natural systems.[32]

Educational tools that embed policy literacy into scientific course offerings are likely to be more effective than other approaches, such as distribution requirements or stand-alone training opportunities. Treating policy in a separate course could unintentionally reinforce the notion that societal knowledge stands apart from day-to-day scientific work. This approach resonates with pedagogical research that addresses challenges in interdisciplinary teaching and learning[21]

Measuring the effectiveness of methods for teaching policy literacy should be part of evaluating any new climate science course or curriculum. Since it is likely that case studies, simulations, and other activities may be differentially effective in promoting policy literacy, evaluation is necessary to further progress in this area. As an example, we conducted an evaluation of the learning that occurred through the Mercury Game, using pre- and postsurveys after the activity was administered in classrooms across North America.[29]

CONCLUSIONS

We recommend that policy literacy become a component of standard graduate scientific education, integrated into the curriculum. We also suggest further development and use of curricular modules for this purpose. This need not be limited to the core subjects of climate science, but could also be addressed when students are learning in related fields. For example, related chemistry courses might pair learning about stratospheric ozone chemistry with a case study of international negotiations to address its depletion. Students learning about nuclear energy production may benefit from reading about or engaging with local communities surrounding power plants. In addition to encouraging the policy literacy, such approaches could also help make climate science more relevant and exciting to a broader, more diverse range of future scientists.

Coordinated efforts are necessary to evaluate and track scientists' overall policy literacy. Surveys showing that the public lacks scientific knowledge receive national media attention. Policy literacy among scientists is equally important in bridging the science–society gap, but receives virtually no attention in surveys or the media. In particular, the U.S. National Science Foundation (NSF), which conducts surveys of public scientific literacy and compiles statistics on the U.S. scientific work force, could include indicators of scientists' policy literacy in these existing efforts.

We recognize it may be difficult for professors to integrate the policy literacy education into a traditional climate science curriculum. Challenges faced by faculty may include existing curricular requirements, lack of materials, or skepticism of the value of this approach.[33] In addition, there are tradeoffs to incorporating new material in classes with limited instructional hours. Universities, associations such as AAAS and the American Geophysical Union, and funding agencies such as NSF can promote policy literacy through providing incentives for faculty to develop and enhance relevant skills. Any organization interested in enhancing science communication, science–policy interactions, or science–society relations through building scientific literacy in the public sphere should support parallel efforts to enhance policy literacy among scientists. Exposing future climate scientists to the societal and policy context within which climate change is happening will encourage them to orient their work to inform the most critical climate challenges, and to communicate more effectively with policy-makers and the public. Ultimately, training climate scientists to understand the policy context for their work will improve both our knowledge of climate change and our collective ability to mitigate it.

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REFERENCES

1. Holdren JP. Science and technology for sustainable well-being. *Science* 2008, 319:424–434.
2. Mooney C, Kirshenbaum S. *Unscientific America*. New York: Basic Books; 2009.
3. Kirchhoff CJ, Carmen Lemos M, Dessai S. Actionable knowledge for environmental decision making: broadening the usability of climate science. *Annu Rev Environ Resour* 2013, 38:393–414.
4. Victor D. Climate change: embed the social sciences in climate policy. *Nature* 2015, 520:27–29.
5. Kahan DM, Peters E, Wittlin M, Slovic P, Ouellette LL, Braman D, Mandel G. The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nat Clim Change* 2012, 2:732–735.
6. Pepermans Y, Maeseele P. The politicization of climate change: problem or solution? *WIREs Clim Change* 2016, 7:478–485.
7. National Research Council (U.S.). National Science Education Standards, Washington, DC, 1996.
8. Roberts DA. Scientific literacy/science literacy. In: Abell SK, Lederman NG, eds. *Handbook of Research on Science Education*. New York: Routledge; 2007, 729–780.
9. Bauer MW, Allum N, Miller S. What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Underst Sci* 2007, 16:79.
10. Jasanoff S. *The Fifth Branch: Science Advisers as Policy-Makers*. Cambridge, MA: Harvard University Press; 1998.

11. Peters HP, Brossard D, de Cheveigne S, Dunwoody S, Kallfass M, Miller S, Tsuchida S. Science communication. Interactions with the mass media. *Science* 2008, 321:204–205.
12. Somerville RCJ, Hassol SJ. Communicating the science of climate change. *Phys Today* 2011, 64:48–53.
13. Weber JR, Word CS. The communication process as evaluative context: what do nonscientists hear when scientists speak? *BioScience* 2001, 51:487–495.
14. Slovic P. Informing and educating the public about risk. *Risk Anal* 1986, 6:403–415.
15. Dudo A, Besley JC. Scientists' prioritization of communication objectives for public engagement. *PLoS One* 2016, 11:1.
16. Mitchell RB, Clark WC, Cash DW, Dickson NM. *Global Environmental Assessments: Information and Influence*. Cambridge, MA: MIT Press; 2006.
17. American Association for the Advancement of Science. AAAS science and technology policy fellowships job announcement, 2013. Available at: http://perjobs.blogspot.com/2013/09/science-technology-policy-fellowships.html. (accessed December 9, 2016).
18. MORI Wellcome Trust. The Role of Scientists in Public Debate, London, 2000. Available at: https://wellcome.ac.uk/sites/default/files/wtd003425_0.pdf. (accessed December 9, 2016).
19. Mulder HAJ, Longnecker N, Davis LS. The state of science communication programs at universities around the world. *Sci Commun* 2008, 30:277–287.
20. DeZure D. Essays on teaching excellence. *Toward the Best in the Academy* 1999; 10.
21. Sternberg RJ. Interdisciplinary problem-based learning. *Lib Educ* 2008, 94:12.
22. Boix-Mansilla V. Learning to synthesize: the development of interdisciplinary understanding. In: Frodeman R, Klein JT, Mitcham C, eds. *The Oxford Handbook of Interdisciplinarity*. Oxford, UK: Oxford University Press; 2010, 288–309. 0199236917.
23. Handelsman J, Ebert-May D, Beichner R, Bruns P, Chang A, DeHaan R, Gentile J, Lauffer S, Stewart J, Tilghman SM, et al. Education. Scientific teaching. *Science* 2004, 304:521–522.
24. Prewitt K, Schwandt TA, Straf ML. *Using Science as Evidence in Public Policy*. Washington, DC: National Academies Press; 2012.
25. Wei CA, Burnside WR, Che-Castaldo JP. Teaching socio-environmental synthesis with the case studies approach. *J Environ Stud Sci* 2015, 5:42–49.
26. Rumore D, Schenk T, Susskind L. Role-play simulations for climate change adaptation education and engagement. *Nat Clim Change* 2016, 6:745–750.
27. Susskind L, Rumore D, Hulet C, Field P. *Managing Climate Risks in Coastal Communities*. London: Anthem Press; 2015.
28. Sterman JD, Fiddaman T, Franck T, Jones A, McCauley S, Rice P, Sawin E, Siegel L. Management flight simulators to support climate negotiations. *Environ Model Software* 2013, 44:122–135.
29. Stokes LC, Selin NE. The mercury game: evaluating a negotiation simulation that teaches students about science-policy interactions. *J Environ Stud Sci* 2016, 6:597–605.
30. Selin NE. Teaching and learning from environmental summits: COP-21 and beyond. *Glob Environ Polit* 2016, 16:31–40.
31. Bennett J, Lubben F, Hogarth S. Bringing science to life: a synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Sci Educ* 2007, 91:347–370.
32. National Association of Geoscience Teachers. On the cutting edge: professional development program for geoscience faculty, 2016. Available at: http://serc.carleton.edu/NAGTWorkshops/index.html. (accessed December 9, 2016).
33. Anderson WA, Banerjee U, Drennan CL, Elgin SCR, Epstein IR, Handelsman J, Hatfull GF, Losick R, O'Dowd DK, Olivera BM, et al. Science education. Changing the culture of science education at research universities. *Science* 2011, 331:152–153.