Evolving Attitudes of Science Graduate Students Toward Science Policy and Communication

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Executive Summary: Widespread changes in the exchange and politicization of science have made it imperative for scientists to be prepared to engage in science communication and science policy. Separately, science graduate students express interest in a more diverse array of career trajectories beyond the traditional academic research path. These forces together inspire changes to graduate education to develop critical science communication and policy skills. However, universities remain focused on training students in primarily academic research skills. This case study measured changes to beliefs about and participation in science communication and policy among science graduate students over three years to better understand the evolution of interest in these practices. Importantly, not only did students report a significantly increased interest in and belief in the importance of science communication and policy, but also these increases were observed regardless of their initial beliefs. Graduate students also provided qualitative feedback about the reasons behind these changes and perceived barriers to participating in science communication and policy. These data help to both motivate universal changes to graduate education to include science communication and policy and to inform stakeholders on how these changes can be optimally designed to address barriers and interests. Finally, corresponding policy changes are recommended to departments, universities, scientific societies, and other stakeholders to enact effective change to graduate training.

I. Introduction

In recent decades, challenges to implementing science into public and societal decision-making have forced scientists to reexamine the importance of science communication and policy in their careers. These challenges can arise firstly from the ways in which science is shared and consumed. The broader public receives science information through mainstream media, where reporting often fails to convey key details and nuance (Cassels et al. 2003; Dempster, Sutherland, and Keogh 2022). More recently, science is often communicated via social media, where susceptibility to misinformation can greatly affect public opinion (Lee, Tandoc Jr. Lee 2023). The inability to convey the complexity of scientific research – or intentional withholding of information – in all forms of media leads to misinterpretation and even blatant refusal to accept new conclusions (West and Bergstrom 2021). Secondly, perception of science is highly polarized along political lines, especially in the United States. This leads to questioning of methodologies, institutions, and facts on which there is scientific consensus regarding topics from genetically modified foods to vaccine efficacy and beyond (Stjernquist 2020; Jewett 2020). Importantly, these problems in communication and understanding affect policy as well. The general public's perception plays a major role in how policymakers prioritize issues such as research funding and legislation pertaining to science (Schaffer, Oehl, and Bernauer 2022). These forces have come to the forefront of

many scientists' minds with the COVID-19 pandemic, as well as other pressing concerns like climate change.

For these reasons, developing strong, evidence-based policies and strategies to communicate science has become more critical than ever. Scientists' interactions with both the general public and policymakers should be a bidirectional dialogue that educates non-scientists about scientific discovery and informs the research community on society's needs and values (Leshner 2003). In this way, scientific research can be democratized and optimally designed to address those needs. Additionally, development of robust science policy and communication practices that aim to inform public opinion of science can lead to an increase in research funding (Muñoz, Moreno, and Luján 2012; Besley 2018). If one of the ultimate goals of scientific research is to positively impact human lives, scientists need to help address the ways in which the general population and lawmakers interact with science.

Independent of the growing importance of science communication and policy, the interests and career aspirations of science graduate students have shifted dramatically in the last few decades. The National Science Foundation reported a decrease in the percentage of science doctorate recipients that hold an academic research position after graduation, with an especially low proportion holding a permanent position in academia such as faculty (National Science Foundation 2019). Across the world, current graduate students show a decreased interest in academic research careers, with less than half expressing that they would prefer to work in academia (Woolston 2022). Despite the changing landscape of graduate student goals, training of early-career researchers has scarcely adapted to these needs. Science graduate students describe a growing dissatisfaction with their graduate training because of the lack of support for non-academic job transitions (Ganapati and Ritchie 2021; McDowell et al. 2015). While many universities may offer a variety of professional development resources, their optional nature, requisite time commitment, and overwhelming focus on research careers still leaves graduate students feeling ill-prepared. For those students with an interest in science policy and/or science communication, such resources can be especially limited. Early-career researchers must explore these subjects through either a separate formal degree program or organizations outside of higher education, such as the National Science Policy Network or the Union of Concerned Scientists. These resources satisfy strongly motivated students but leave most untrained in science policy and communication skills. The next generation of scientists is therefore not being prepared to meet the demands of communicating science in society.

Despite these trends, no previous work has attempted to track attitudes toward science policy and communication among science graduate students to describe any changes and their underlying causes. This information can motivate reform to science graduate education to better address current students' goals and interests. Therefore, this work presents a case study that identifies patterns in the beliefs and behaviors of science graduate students toward science policy and communication over time that may inform potential changes to graduate education.

II. Methods

i. Survey administration and analysis

The study was implemented with local IRB approval (IRB #STU00217983) at Northwestern University in January-February 2023. Study participants were recruited via emails sent to active science graduate student organizations and departments. Study participation lasted the duration of a survey, or approximately 20 minutes. The survey was designed by the study's student investigator and administered using Qualtrics. Most of the survey questions were designed as a retrospective pre-post survey that prompted respondents to rate the extent to which they agreed with statements related to their beliefs and behaviors about science policy and science communication currently (in January 2023) and three years prior (in January 2020) on a scale of 1-10, with 1 being "not at all true" and 10 being "absolutely true". Study participants also answered questions about their science policy and communication needs on a Likert scale from "strongly disagree" to "strongly agree" and

short-answer essay questions regarding their perception of changes in beliefs and behaviors over the last three years. For the purposes of this study, science policy was defined as:

"The practice of studying or participating in the development of policies that impact science (funding, education, etc.) or are impacted by science (healthcare, environmental protection, data privacy, etc.) at the federal, state, local, or institutional level."

Science communication was defined as:

"The practice of informing, educating, or raising awareness of science-related topics to the broader public, such as through outreach, science journalism, social media, public talks, and more."

Statistical analysis on survey data was performed using a paired sample t-test to determine significant differences in individuals' response between the January 2020 and January 2023 time points where appropriate.

ii. Study participants

The study was implemented at Northwestern University, a mid-size, private, R1 institution with a total graduate population of over 14,000 students. Inclusion criteria for study subjects were that they were active Master's or Ph.D. students in a science department (n = 111), and most respondents were Ph.D. students (88% Ph.D., 11% Master's, 3% dual degree). Science departments were not explicitly defined so as to include survey respondents from a wide range of disciplines, including engineering (33%), life sciences (31%), physical sciences (23%), social sciences (7%), formal sciences (3%), and other science disciplines (3%). Study participants were evenly distributed across year in graduate school (24% 1st year, 28% 2nd year, 16% 3rd year, 14% 4th year, 18% 5th year or higher). 68% of survey respondents were female and 55% of respondents identified as a minority in their discipline. Attrition rates for survey participation were 13%.

III. Results and discussion

Study participants rated the extent to which they agreed with statements related to science policy and communication on a sliding scale based on their beliefs currently (2023) and three years prior (2020). There was a statistically significant increase in positive scores over time for statements regarding personal interest in learning about and developing skills related to both science policy ($p = 1.4E-17$, $p = 2.8E-16$, respectively) and science communication ($p = 5.7E-14$, $p = 1.2E-12$, respectively), with less than 7% of respondents reporting a decrease in score over time for each of the four statements (Figure 1). Scores that reflected these interests in 2023 also decreased in variance compared to those collected for 2020, indicating a greater agreement among survey respondents on having appreciable interests in science policy and communication. Intriguingly, the statements with the highest mean scores for their respective category (science policy or communication) in 2023 reflected the belief that science policy or science communication "is an important subject that all graduate students should learn about" (Figure 1). Scores for these statements also demonstrated a statistically significant increase between 2020 and 2023 for science policy ($p = 4E-17$) and science communication ($p = 4.9E-15$). Finally, scores for statements probing participation and career interest in science policy and communication also displayed statistically significant increases between 2020 and 2023 (Figure 1). Science graduate students therefore express not only increased interest in and appreciation for the importance of these topics, but also development of an active commitment involving time and effort beyond their traditional graduate studies. Changes in beliefs and behaviors did not significantly differ based on demographic minority status or student status in 2020.

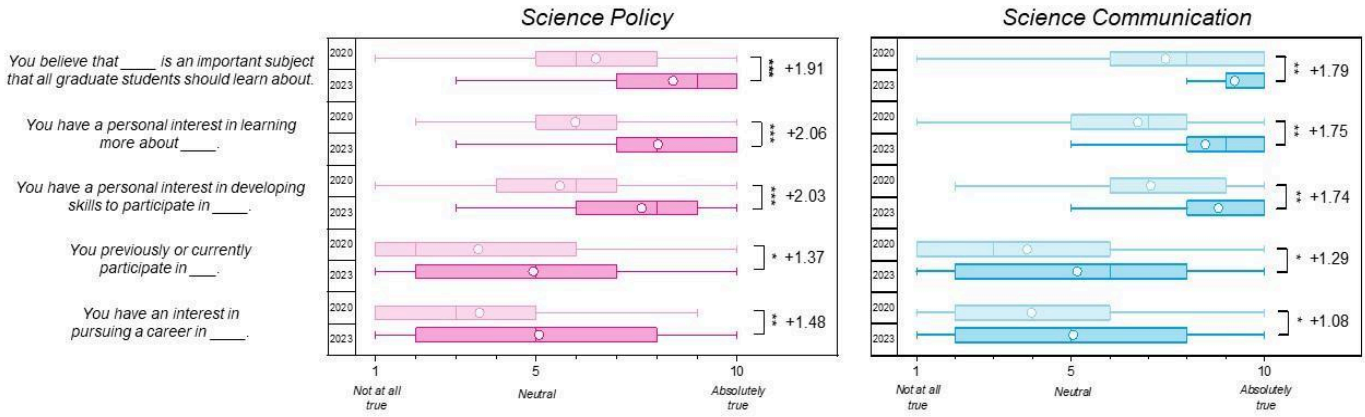

Figure 1. Box plot showing the quartile range and mean (circle) of survey responses on a scale of 1-10 answered for January 2020 (light) and January 2023 (dark) for statements regarding science policy (pink) and science communication (blue). The change in mean score between 2020 and 2023 is indicated for each statement and statistical significance is denoted by *** $p < 1E\text{-}15$, ** $p < 1E\text{-}10$, and * $p < 1E\text{-}6$.

A central observation from comparing scores between 2020 and 2023 is that, for each statement, nearly all survey respondents self-reported an increase in score over time. For each of the 10 statements examined in Figure 1, > 91% and > 85% of participants maintained or increased their agreement for the science policy and science communication categories, respectively. In fact, students self-report increases in scores over time *regardless of their initial score in January 2020*. For all ten statements shown in Figure 1, the average absolute magnitude change in score was positive or zero when categorized by the initial score in January 2020 (Figure 2). This demonstrates a uniform increase in positive attitudes toward science policy and communication across all levels of interest and involvement. Simply put, overall increases in positive beliefs and behaviors toward science policy and communication are attributable not just to a small subset of respondents; rather, nearly all show modest increases. This finding in particular should motivate institutional policy changes to create universal training in science policy and communication in science graduate programs.

Respondents gave qualitative feedback on why they believe their answers to these questions changed over time, which were grouped into several themes. The most cited reasons for increases in positive beliefs toward science policy and communication were increased awareness of the topics and considering career paths beyond academia. Several comments mentioned recent events, remarking, for example, that "the pandemic highlighted the lack of science literacy, often in part due to poor science communication" and that they felt motivated to act by witnessing that "science policy is being implemented by people who have little to no knowledge of the 'true' impacts to the community at large." Students also noted their desire to increase the impact of research and that they "realized for [their] research to have an impact now or in the future [they] must be more involved in science policy and communication."

It is equally important to recognize forces that worked against these motivations. Notably, comments did not emphasize decreased interest in the subjects, but rather a competition of time and effort with other graduate school responsibilities, not viewing them as "a viable stable career path," and/or discouragement by faculty and the university environment. While instances of being actively dissuaded from pursuing these subjects by advisors were reported, respondents more often described a broader apathy of their surrounding network toward science policy and communication. For instance, they reported a perceived incompatibility with research goals, expressing that "people do not want to deal with things that don't secure them funding." One comment explained, "There is just a limit to how

much I can invest in science policy and communication career development when it is not compensated or supported by my department." This feedback highlights critical barriers to graduate student participation in science policy and communication, but requires further exploration to understand the relative contributions of these factors on a greater student population.

Lastly, study participants were nearly evenly split over whether they agreed that their interest in science policy or communication "is being met by the resources currently available to [them]." Importantly, 35.8% of participants disagreed or strongly disagreed that their science policy training needs are being met, and 33.9% of participants disagreed or strongly disagreed that their science communication training needs are being met (Figure 3a-b). There is therefore substantial room for growth in meeting the needs of science graduate students to learn about and participate in both science policy and communication. Further, 85.3% of participants agreed or strongly agreed that they "would like to see an increase in programming and resources available to [them] related to science policy and science communication" (Figure 3c). Given their fundamental role in providing training resources and setting expectations to prioritize diverse training experiences, this unmet need could be addressed by universities themselves. Such training would give early-career scientists the skills to meet the demand for strong science communication to the broader public. The most requested formats for new programming by survey respondents were seminars and interactive workshops, both of which universities regularly provide for other topics. Popular topics suggested by survey respondents for such training included analyzing policy proposals, understanding decisions by funding agencies, translating research findings to non-scientists, lobbying, and preparing for careers in communication and policy.

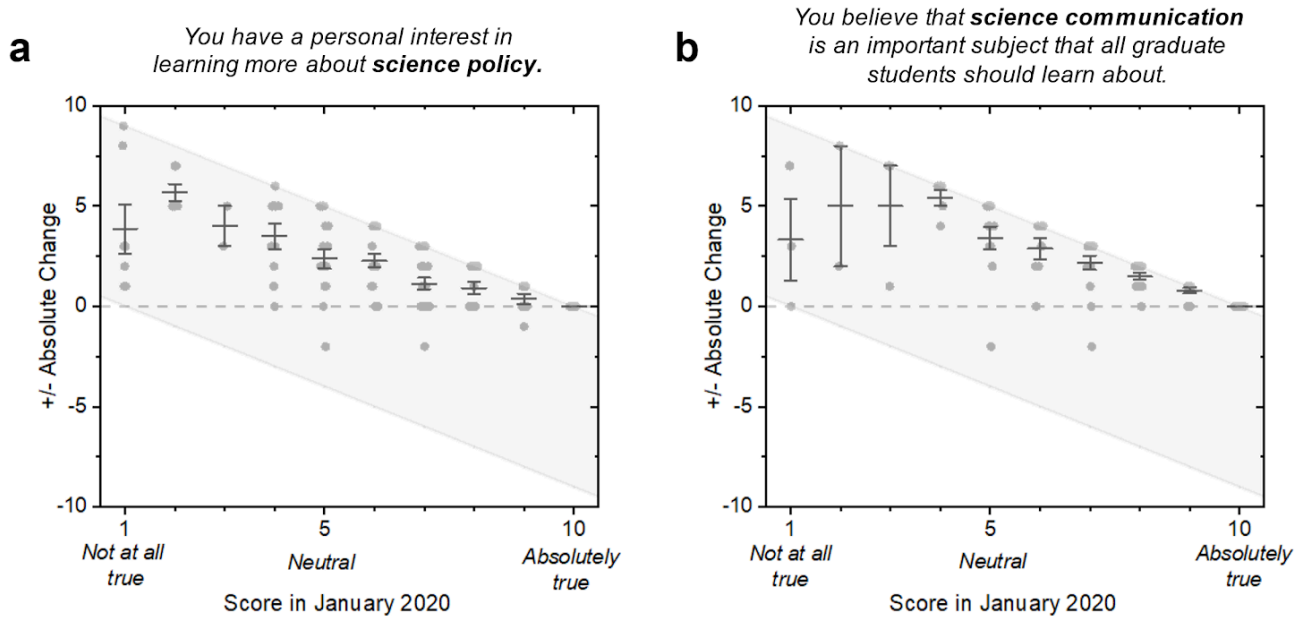

Figure 2. Box plot of absolute magnitude changes in score between January 2020 and 2023 for two representative survey statements. The dashed line represents no change in score, while the shaded region represents the range of potential absolute score changes given the score in January 2020.

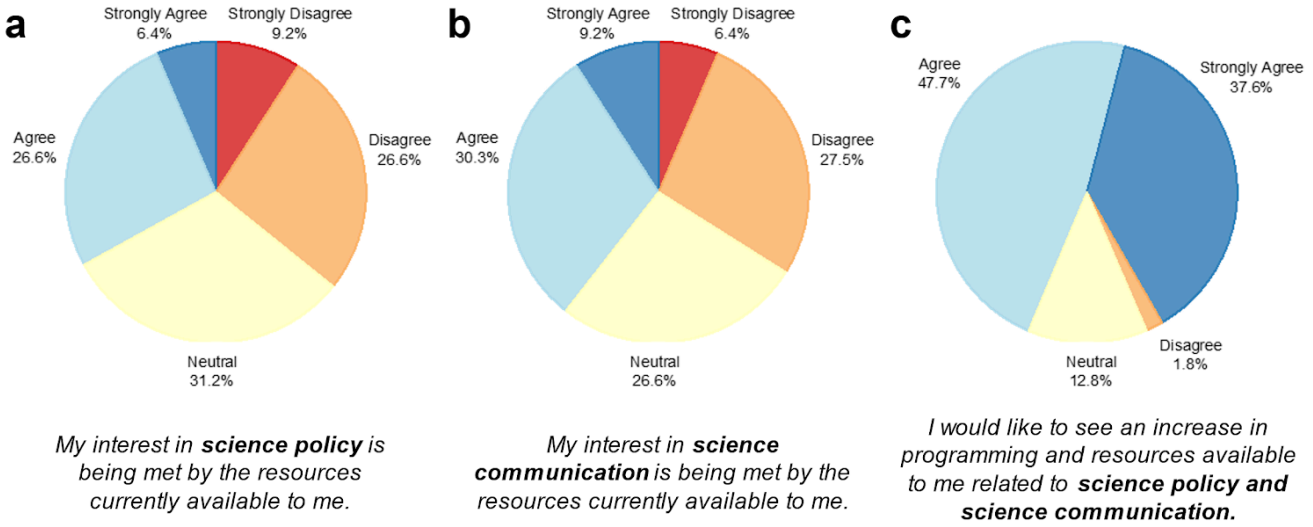

Figure 3. Pie charts of survey respondent agreement with statements about resource availability related to science policy and science communication.

This work aims to serve as a representative case study for beliefs of the science graduate student population but includes caveats to consider. First, each university is unique in its training resources and support, particularly across different geographic regions, cultures, and types of higher education institutions. Northwestern University offers both student-run science policy and communication groups and several science communication courses, which may bias responses compared to universities with fewer training opportunities. Second, given the voluntary nature of the survey, participants may have had greater interest in science policy and communication than the average graduate student. Survey demographics revealed that women and Ph.D. students were overrepresented among respondents compared to the student body. Third, this work cannot definitively isolate reasons underlying reported changes. For example, those who were undergraduate students in 2020 may have experienced large changes simply from entering graduate school and becoming more aware of issues in scientific research. Finally, the retrospective survey questions have an inherent limitation that students may not accurately remember their beliefs and ideas from three years prior and their subjective estimates may be biased.

IV. Policy recommendations

The data presented here clearly demonstrate that graduate students at Northwestern University have increased their belief in the importance of science communication and policy and that there is an unmet need for training and resources that develop these skills. Science graduate students have seemingly acknowledged recent trends in how the general public interacts with science, such as political polarization and information flow through social media, by adapting their personal interests and goals to prioritize science policy and communication. To best train their students for their future role in society and meet these growing interests, universities must follow suit. The following proposed policy changes represent a range of time and effort intensity to achieve these goals.

i. *Policy changes to graduate education*

Institutional policy changes can focus on integrating science policy and communication skill development into existing venues of graduate education. Universities rarely offer entire courses dedicated to science policy or communication, and existing courses on these topics are either not designed for science graduate students or don't count toward their graduation requirements. Departments can cater to student needs by offering such courses,

ensuring that courses fulfill graduation requirements, or even simply adding science policy and communication case studies into elective courses. For example, a graduate course on atmospheric chemistry could also teach communication skills specific to sharing burgeoning climate change research with a non-scientist audience, or a course on biomaterials might include discussion time on recent policy decisions on medical device regulation and clinical trials. These lessons could be easily tailored based on the class, department, or even university. This would help to address the large percentage of graduate students who report that their interest in science policy and/or communication is not being met by their current resources. Beyond the classroom, graduate education commonly takes place through seminars and workshops. Important subjects like research ethics, grant writing, reading scientific papers, and academic career development are expected to be covered, but faculty can have strong influence on selecting other topics. A seminar dedicated to science communication and/or policy training each semester could easily supplement other ongoing training seminars.

While these recommendations may be implemented by individual departments, they are easily scalable to develop school- and university-wide policies that oblige changes to core graduate instruction across disciplines. The greatest advantage of these proposed changes is accessibility to graduate students: by incorporating science policy and communication learning directly into existing curricula, there is minimal strain added to their already difficult training requirements. However, they would also require substantial buy-in and knowledge by the individual faculty that lead courses and seminars. Faculty have their own demanding responsibilities that limit their ability to participate and often have little experience in science policy and communication, having devoted their effort to a traditional academic research career. Overcoming these barriers would likely require significant top-down support and incentivization from university leadership and offices.

ii. *Policy changes to research assessment by universities*

Institutional policy changes can further reform graduate education by redefining what it means to be a successful scientist. Like other researchers, graduate students are predominantly assessed by quantifiable metrics such as publications, funding, and awards. Universities are instrumental in setting these standards, and the lack of value they place on science policy and communication is clear to students. Unless assessments of the quality of early-career researchers' work are redefined to appreciate science communication and policy, these ventures will continue to be treated as an extracurricular activity that competes with the time and effort of traditional scientific research and will remain inaccessible to many students. Qualitative comments made by survey participants identified this as a barrier to participation because science communication and policy activities are currently "not compensated or supported by [the] department." As a result, universities will continue to produce scientists inadequately trained for the diverse responsibilities they now hold in society.

To begin changing how students are assessed, universities should normalize an expectation for science policy and communication work by incorporating it into graduate student progress reports, such as committee meetings and thesis writing. Universities could offer increased awards for this work to acknowledge its value, or even seed grants to support new policy and communication projects. For example, University of Wisconsin-Madison recently began partnering with the Wisconsin Initiative for Science Literacy (WISL) to monetarily award Ph.D. graduates with outstanding thesis chapters communicating their research to non-scientists, including members of Congress (University of Wisconsin-Madison 2023). Universities can even further revise standards of excellence placed on all scientists by considering policy changes for other researchers and faculty. Much in the same way that diversity statements have become normalized during faculty hiring, science policy and communication experiences could be shared during the application process. Entire institutions could follow recommendations put forth by the Declaration on Research Assessment, a

movement to reinvent means of research assessment beyond journal impact factor (DORA 2023). These practices have led some institutions to focus on more holistic evaluation of researcher success that highlights the diversity of activities that researchers may engage in, including societal impact and interaction (Universiteit Leiden, n.d.; Working group for responsible evaluation of a researcher 2020). While these larger goals have the power to dramatically improve acceptance of science policy and communication work by changing research culture expectations, they would require even more deliberate top-down university support, which universities are unlikely to provide alone. To address this, we must simultaneously pursue policy changes in research assessment amongst other groups, as detailed below, to incentivize universities to change.

iii. *Policy changes outside of higher education*

Other stakeholders in the research community, including those outside of academia, can help redefine scientific success and motivate universities to pursue the above institutional policies. Several professional science societies already offer awards and fellowships dedicated to science policy and communication that recognize the work of students who have devoted significant time outside of their traditional research. For instance, the American Geophysical Union and the Society for Neuroscience each offer a yearlong, part-time science policy fellowship for early-career scientists, and the prestigious National Academies of Sciences, Engineering, and Medicine highlights talented scientists with Awards for Excellence in Science Communications (AGU; SfN; NASEM). These efforts to recognize graduate students can be intensified, particularly by increasing the number of smaller awards to increase broader accessibility. These awards and other events hosted by professional societies can also be used to introduce science policy and communication to graduate students, rather than focus solely on students who have already pursued these endeavors successfully. Because awards and funding are already prioritized in higher education, universities would more easily recognize these as valuable.

The federal government could influence changes to science policy education as well. A scientific workforce with the skills to properly communicate and evaluate the impact of science is beneficial to government agencies who employ scientists. Overall, improving the science policy and communication skills of the scientific workforce that runs such agencies leads to fewer upfront training needs for new hires and greater efficiency in implementing scientific discoveries. Therefore, the federal government could consider financially supporting broader changes to graduate education by providing small grants to universities to carry out the proposed policy changes discussed above, such as coursework, seminars, and internal university awards. Funding could be more easily secured by combining small contributions from several federal agencies who could benefit from these actions, many of which operate with tens of billion-dollar annual budgets, such as the National Institutes of Health, National Science Foundation, National Aeronautics and Space Administration, and the Department of Defense (American Institute of Physics 2022). This funding would supply the top-down support at individual universities needed to initiate many of the proposed policy changes detailed above.

Perhaps the greatest obstacle to achieving these policy changes is resistance from those that endorse a traditional graduate education focused solely on academic research, both within and outside universities. But as the role of science in society and the positions that scientists hold continue to evolve, it is imperative that scientist training evolves as well. The widespread awareness of science policy and communication during the COVID-19 pandemic has created important momentum for its incorporation into graduate education. In this work, science graduate students voice an unmistakable increase in interest in and belief in the importance of science policy and communication. These changes are demonstrated broadly across students regardless of their initial beliefs in 2020, and even include increases in active participation in science policy and communication. Universities should use these data as inspiration to create the universal education in science policy and communication that our communities both want and need – making science's impact on the world that much more powerful.

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