BROADENING HORIZONS

How STEM-in-Society Programs Train Socially Responsible Scientists, Engineers, and Policy Leaders

GERALD R. FORD SCHOOL OF PUBLIC POLICY
SCIENCE, TECHNOLOGY, AND PUBLIC POLICY
UNIVERSITY OF MICHIGAN

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About the Science, Technology, and Public Policy Program

The University of Michigan's Science, Technology, and Public Policy (STPP) program is a unique research, education, and policy engagement center concerned with cutting-edge questions that arise at the intersection of science, technology, policy, and society. It is dedicated to a rigorous interdisciplinary approach, and working with policymakers, engineers, scientists, and civil society to produce more equitable and just science, technology, and related policies. Housed in the Ford School of Public Policy, STPP has a vibrant graduate certificate program, postdoctoral fellowship program, applied research projects, public and policy engagement activities, and a lecture series that brings to campus experts in science and technology policy from around the world. Our affiliated faculty do research and influence policy on a variety of topics, from national security to energy.

Funder

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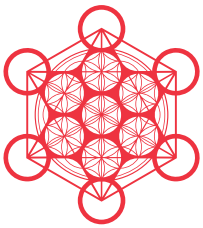

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Acronyms and Definitions

ASU	Arizona State University
Bioethics	A field study and a practice within clinical medicine, medical research, and biological research that focuses on the ethical, social, and legal issues that arise in these settings.
CPE	Continuing professional education. CPE programs referenced in this report are certificate programs offered by a higher education institution that can be taken by individuals who are not otherwise enrolled in a degree program at the host institution.
EPP	Department of Engineering and Public Policy, Carnegie Mellon University
N&PP	Neuroscience and Public Policy Program, University of Wisconsin–Madison
PIT	Public interest technology
Public interest technology	"The study and application of technology expertise to advance the public interest."[1]
R1	Doctoral granting universities that have very high performance in research and development
Science and technology studies	The study of how science and technology are embedded within social systems, including how scientific knowledge and technological systems impact individuals and communities.
SFIS	School for the Future of Innovation in Society, Arizona State University
SJRC	Science and Justice Research Center, University of California, Santa Cruz

SJTP	Science and Justice Training Program, University of California Santa Cruz
STEM	Science, Technology, Engineering, and Math
STEM-in-Society program	Any undergraduate or graduate degree, minor, or certificate program that emphasizes how science, technology, engineering, or medicine intersect with ethics, policy, or society.
STP	Science and technology policy
STPP	Science, Technology, and Public Policy Program, University of Michigan
STS	Science and technology studies
UC Santa Cruz	University of California Santa Cruz
U-M	University of Michigan
UW–Madison	University of Wisconsin–Madison
Virginia Tech	Virginia Polytechnic Institute and State University
Virginia Tech STS	Department of Science, Technology, and Society, Virginia Tech

Executive Summary

As science and technology become more central to our daily lives, there is great need for STEM professionals and other leaders who can conduct or evaluate socially responsible research and innovation, collaborate across disciplinary boundaries, and develop better science and technology policies for the public interest. The traditional disciplinary silos of the university—particularly in STEM fields—do not adequately prepare current or future generations for these roles. Addressing the world's problems requires true multi-disciplinary training that brings humanistic, social scientific, and STEM insights together to help students understand how science, technology, engineering, or medicine intersect with ethics, policy, and society. Science and technology studies (STS), science and technology policy (STP), bioethics, and other similar programs across the United States offer this education to graduate, undergraduate, and mid-career professionals, but they tend to be underfunded and largely ignored by university administrators and science funders. This report analyzes the landscape of these programs (which we refer to collectively as STEM-in-Society programs) and offers recommendations on how they might be strengthened and expanded.

Our landscape assessment employed a mixed methods approach. First, we identified 247 STEM-in-Society degree, minor, or certificate programs hosted by 90 higher education institutions across the United States and analyzed their websites to identify their educational goals and audiences served. To supplement information available on program websites, we then surveyed these programs and received 82 responses. Finally, we developed five case studies and one program snapshot to ground our broad-scale field scan findings in the lived experiences of program leaders, faculty, staff, students, and alumni.[2] These included Carnegie Mellon University's Department of Engineering and Public Policy; Virginia Tech's Department of Science, Technology, and Society; University of Michigan's Science, Technology, and Public Policy Program; University of California, Santa Cruz's Science and Justice Research Center; the School for the Future of Innovation and Society at Arizona State University; and the Neuroscience and Public Policy Program at University of Wisconsin–Madison.

Each case represents a research center, department, or school that confers at least one STEM-in-Society degree, minor, or certificate, and, in total, we completed 78 interviews. Together, the cases represent the breadth of programs identified in our initial scan and include a range of geographic locations, program ages, student audiences, and degree types. Overall, our landscape assessment identifies the shared challenges and opportunities that arise for STEM-in-Society programs. It also describes how STEM-in-Society training impacts alumni career outcomes and professional experiences. We close the report with recommendations for funding organizations, university leaders, and STEM-in-Society program administrators to develop, support, sustain, and expand the reach of such programs.

Who Do STEM-in-Society Programs Serve?

STEM-in-Society programs are unevenly distributed across different types of higher education institutions with most programs hosted by large R1 universities. This means that program faculty are engaged in active research, and students can participate in these projects and also access research-oriented faculty across disciplines. Meanwhile, students at minority serving institutions, liberal arts colleges, and R2 universities lack similar access to this important training. Further, the universities offering these programs typically have multiple versions administered by several different campus units. This requires leaders to establish clear program identities, learning objectives, and alumni outcomes in order to demonstrate their value to prospective students, leverage funding, and pursue collaborations with STEM experts.

There is also great variation in program focus and target audience. Over half offer science and technology studies (STS) training, and the majority of these are undergraduate programs. The next most common field was bioethics, followed by science and technology policy. With the exception of STS programs, the majority of STEM-in-Society programs target graduate students. Comparatively few STEM-in-Society programs offer continuing professional education (CPE), i.e., certificates available to individuals who are not enrolled in another degree program. CPE programs are also limited in scope, usually focusing on bioethics or niche topics in science and technology policy (e.g., Neuroscience and Public Policy). The scarcity of CPE programs could reflect a historical lack of demand for these programs, but the growing awareness of social and policy challenges associated with emerging science and technology makes it imperative for professionals to have STEM-in-Society training options available to them.

In many cases, STEM-in-Society training supplements a primary degree program and provides students with STEM backgrounds a broader perspective, explicit training in how to be more socially or ethically responsible, and/or the potential to shift their careers or professional foci. Non-STEM students who pursue STEM-in-Society training are often aspiring policy or business leaders who increasingly realize that they must understand the relationships between science, technology, and society to better address the world's problems. STEM-in-Society programs try to respond to these varying backgrounds and needs by offering flexible degree options. Both our landscape scan and case studies illustrate the importance of providing STEM-in-Society students with the flexibility to pursue interdisciplinary interests; add this training as a supplement to their primary degree without over-burdening their workload; and complete their chosen program in-person, online, or in a hybrid format. Some undergraduate minor and graduate certificate programs, for instance, are designed to be completed in tandem with students' primary degree programs without adding additional time to students' graduation plan.

STEM-in-Society Programs Expand Skills for Technical Experts

Students and graduates of STEM-in-Society programs gain knowledge and skills that enable them to conduct more responsible research, work across a broad array of professional sectors, and inform science and technology policy. Interdisciplinary training prepares STEM-in-Society graduates for translational roles. These include collaborating in multidisciplinary teams, serving as issue area experts in public service or policy roles, and promoting more ethical research. More holistic training for engineering students equips them with social analysis, project management, and writing skills, which can shift how they approach their work and broaden their understanding of related career options. STEM-in-Society training also prepares graduate students who go on to academic or private sector research careers to conduct more responsible research. In some cases, STEM-in-Society trained researchers are more likely to incorporate social considerations into their research or seek postdoctoral positions that emphasize the intersection of society and STEM research.

Despite their Importance, STEM-in-Society Programs are Precarious

While many universities emphasize their interdisciplinarity across campus to respond more effectively to the world's challenges, STEM-in-Society program leaders spend a good deal of time justifying their program(s) to campus leaders to retain their status and budget. One challenge is that these programs do not easily fit into traditional disciplinary structures or accreditations. This is further exacerbated for multi- or interdisciplinary STEM-in-Society programs that draw together faculty expertise across campus units. Furthermore, STEM-in-Society training is often less valued due to pervasive bias against the humanities and social sciences that positions STEM fields as more legitimate and important. This is further complicated for STEM-in-Society programs because they are often smaller in terms of their student enrollment, and higher education administrators often assess program value based on the number of degrees they award annually. Even when they do enroll students directly, these programs are benchmarked against traditional disciplines rather than STEM-in-Society programs at other universities, which makes them look less successful than they are. At the same time, these programs provide a variety of campus-wide services in the form of general education courses, student research opportunities, and ethics training for STEM majors. But because these activities do not generate program revenue, university administrators rarely pay attention. External funders and other leaders have a crucial role to play here, both communicating to university administrators the importance of STEM-in-Society programs, and supporting them directly.

Varied Career Outcomes, Insufficient University Support

STEM-in-Society program alumni work across a range of sectors, including academia, government, industry, and non-profit organizations. Those pursuing scholarly careers incorporate responsible research and ethical considerations into their STEM research and are more likely to work across disciplines to address complex science and technology issues. Some are even attempting to recreate their own STEM-in-Society training experience in a new university context, demonstrating the positive ripple effects of this training across the country. Graduate students who combine rigorous STEM training with a supplementary STEM-in-Society certificate or degree often pursue non-academic careers in public policy or government agencies where they can leverage both knowledges and skill sets.

While graduates seeking job opportunities benefit from this broad applicability of STEM-in-Society training, it can be quite difficult for program faculty and staff to offer appropriate career services. Most STEM-in-Society faculty have only worked in academia, their programs are under-staffed, and university-level career services staff lack the necessary knowledge and employer networks to best serve students and alumni. Like the university administrators we describe above, they too tend to think in terms of disciplinary silos and more traditional career paths. As a result, STEM-in-Society programs leverage their own alumni networks to help fill this void. However, interviewees across programs agreed that STEM-in-Society students need better assistance developing their professional identities, understanding the state of potential employers and related careers, and building their professional networks.

The Benefits and Risks of Proliferating STEM-in-Society Programs

We might assume that with growing public interest in the relationships between science, technology, and society, particularly with the rise of AI and other technologies, STEM-in-Society programs would be in an excellent position to secure additional funding to expand their educational programs and research partnerships. However, instead we have seen a sharp increase in STEM-in-Society research conducted by STEM-trained academics. While this has the potential to engage more STEM trainees and increase responsible research and innovation, it lacks systematic expertise from the humanists and social scientists who have sustained knowledge on these issues and who come from fields like science and technology studies, ethics, or science policy. This

also harms students, who cannot learn the full range of STEM-in-Society insights and conceptual toolkits, and limits the ultimate benefits to science, technology, and related public policies. Further, these new initiatives can hurt long-standing STEM-in-Society programs and their associated faculty. Despite their considerable expertise, they are often on the outside looking in because STEM departments have more institutional clout, and university administrators assume that because they understand the technical details involved, they have a better understanding of the social and ethical issues at hand. Ultimately, this reinforces the false idea that humanists and social scientists are peripheral to STEM-in-Society training and research. Not only do humanities and social science-led programs seem dispensable, but it becomes difficult for experts from these programs to build equitable relationships with STEM experts to conduct collaborative and cross-disciplinary research projects—relationships that external funders increasingly seek to cultivate. This further highlights the need for humanities and social science-driven STEM-in-Society training at the earliest stages to prepare faculty, policymakers, advocates, and business leaders who can advocate for truly equitable and interdisciplinary STEM-in-Society training and research.

An Opportunity for Inclusion

Historically disadvantaged and otherwise marginalized communities are underrepresented in STEM fields, while science, technology, and related public policies have disparate negative impacts on these very same communities. However, most STEM-in-Society program curricula and professional development lack dedicated attention to topics related to diversity, equity, inclusion, and justice (DEIJ). This is a missed opportunity for both university administrators and programs themselves. Not only do STEM-in-Society programs have unique knowledge to contribute to public and policy conversations on DEIJ in science and technology, but they could help underrepresented students engage more in STEM topics and even pursue STEM careers. Universities that care about DEIJ could view investments in these programs—particularly, those that increase content on these topics—as progress towards these goals. The few programs that explicitly engage with these topics suggest that such goals are not out of reach.

Recommendations

Our comprehensive analysis suggests that there are rigorous STEM-in-Society programs at higher education institutions around the country training scholars, STEM professionals, policymakers, and advocates dedicated to responsible scientific research, technology, and evidence-based public policies, using a variety of creative methods. However, they tend to be underfunded and ignored by university administrators and funders despite recent initiatives to cultivate

interdisciplinarity and address the social and ethical challenges posed by emerging science and technology. With increased support from funding organizations and university leadership, these programs can increase their impacts. STEM-in-Society programs can also learn from each other, and this report is a first attempt to bring the broader field into focus and identify shared challenges, solutions, and opportunities for growth and increasing impact.

Below, we provide recommendations on how to strengthen and expand the national landscape of STEM-in-Society training programs. We focus our attention on three key audiences of decision makers: funders and other organizations interested in cultivating more responsible scientific research, technology, and evidence-based public policies; university administrators; and STEM-in-Society program administrators and leaders. We hope that this report and recommendations enable deeper understanding and recognition of the ecosystem, provide guidance on the challenges STEM-in-Society programs face and how they might be addressed, and enable mutual learning to strengthen these programs to ultimately train the next generations of leaders to address the world's most wicked problems.

Recommendations for National Organizations Interested in Supporting the STEM-in-Society Ecosystem

DEVELOP THE ECOSYSTEM

- Create long-term funding opportunities that strengthen existing STEM-in-Society programs—particularly those based in the humanities and social sciences—rather than simply launching new ones. These programs provide the intellectual engine for critical understanding of how science, technology, and related public policies both shape and are shaped by societies.

- Recognize and support institution-specific goals. There is no "one size fits all" approach to STEM-in-Society program design (e.g., a small, private liberal arts college will have different needs than a large, public minority-serving institution).

- Convene regular meetings across STEM-in-Society programs to foster mutual learning and potential collaboration.

- Encourage accreditation organizations to require, or at least recognize, the importance of STEM-in-Society training.

EXPAND LEARNING OPPORTUNITIES

- Create more STEM-in-Society fellowship programs for professionals who want to translate their technical expertise and professional experience into a STEM-in-Society career (e.g., NSF postdoctoral fellowships).
- Enable the design, delivery, and evaluation of short-term STEM-in-Society bootcamps or professional workshops for STEM-trained students, postdoctoral researchers, and faculty.
- Collaborate with non-profit organizations, government agencies, and professional associations to support or create STEM-in-Society learning opportunities that operate outside of higher education (e.g., Civic Science Fellows, AAAS science and technology policy fellowships).

FOSTER LEADERSHIP

- Provide strategic planning assistance to help STEM-in-Society programs identify opportunities to increase their education and public engagement impacts.
- Invest in mentorship and professional development programs that foster leadership development for STEM-in-Society faculty, postdoctoral researchers, and staff.
- Create a leadership pipeline to increase STEM-in-Society programs' long-term stability. This might include creating funded opportunities for faculty to shadow a STEM-in-Society program leader, supporting executive coaching for program leaders, and matching early career STEM-in-Society faculty and staff with more experienced mentors.

Recommendations for University Administrators

BUILD INSTITUTIONAL RESOURCES

- Train career services offices to serve students interested in STEM-in-Society programs, and encourage them to develop internship partnerships with STEM-in-Society-focused organizations (e.g., government offices and civil society groups focused on the intersection of STEM and society).
- Foster connections between STEM-in-Society programs and efforts to cultivate research impact (including offices dedicated to supporting PhDs seeking non-academic careers).
- Remove barriers to the creation and marketing of STEM-in-Society programs across campus.
- Remove barriers for students enrolling in STEM-in-Society program courses (e.g., making course approvals and cross-listing courses easier).
- Build financial support for STEM-in-Social programs by ensuring that revenues generated benefit these programs.

- Reconsider tenure and promotion processes to ensure that candidates are not disadvantaged by doing inherently interdisciplinary work.

- Encourage dual faculty appointments between STEM and the humanities and social sciences, but require units to provide plans for tenuring and promoting these unique candidates.

- Encourage accreditation organizations to require, or at least recognize, the importance of STEM-in-Society training.

FACILITATE INTERDISCIPLINARY COLLABORATION

- Encourage STEM programs to require students to take STEM-in-Society courses for their humanities and social science requirements, and take steps to remove relevant barriers.

- Create incentive programs to foster interdisciplinary research across STEM, the humanities, and the social sciences. But this funding should also include support for managing the challenges that interdisciplinarity creates.

- Create public-facing (e.g., on university websites) directories of all STEM-in-Society programs associated with the institutions and their approach and activities.

- Strongly encourage STEM units developing STEM-in-Society courses, programs, or research activities, to collaborate with those located in the humanities and social sciences to ensure that the training provided is rigorous and that they are not co-opting programming from less powerful entities on campus.

- Support campus events showcasing the expertise of STEM-in-Society programs so that those newly interested in these questions become aware of centers of expertise.

- Integrate STEM-in-Society programs into campus efforts focused on responsible research and innovation (e.g., IRBs, research compliance) to improve research while supporting campus STEM-in-Society programs.

CREATE CONSISTENT FUNDING STREAMS

- Provide adequate funding for STEM-in-Society programs, including faculty and staff support, marketing and communications, and student and career services, that enables maintenance but also facilitates adaptability as new science and technology issues emerge.

- Train staff at development offices so that they understand STEM-in-Society programs and can assist with fundraising.

- Provide dedicated fellowships or scholarships for students who seek to enhance their STEM degrees with STEM-in-Society training.

Recommendations for STEM-in-Society Program Leaders

BROADEN STUDENT RECRUITMENT

- To increase enrollment, streamline degree requirements and offer varied formats for courses, including online, weekend, and internship options.
- Develop marketing materials to help students and, as relevant, their families, understand the benefits of participating in a STEM-in-Society program, starting from before they enroll at the university. Consider marketing programs by emphasizing how the world's most difficult challenges require not just interdisciplinarity, but STEM-in-Society knowledge.
- Consider developing a suite of non-traditional educational programs (e.g., continuing professional education, bootcamps, online courses, postdoctoral training fellowships) for STEM and other professionals who want to acquire STEM-in-Society knowledge and skills that will help them advance or pivot in their careers.

ENHANCE CAREER SUPPORT

- Provide career services for students interested in pursuing both academic and non-academic careers, with an eye towards the long-term.
- Help students build their professional identities so they can be more confident and successful on the job market.
- Make program learning outcomes, professional development opportunities, and associated benefits (and trade-offs) transparent for prospective students.
- Track alumni, and leverage alumni networks to broaden students' understanding of career pathways.

LEVERAGE DATA

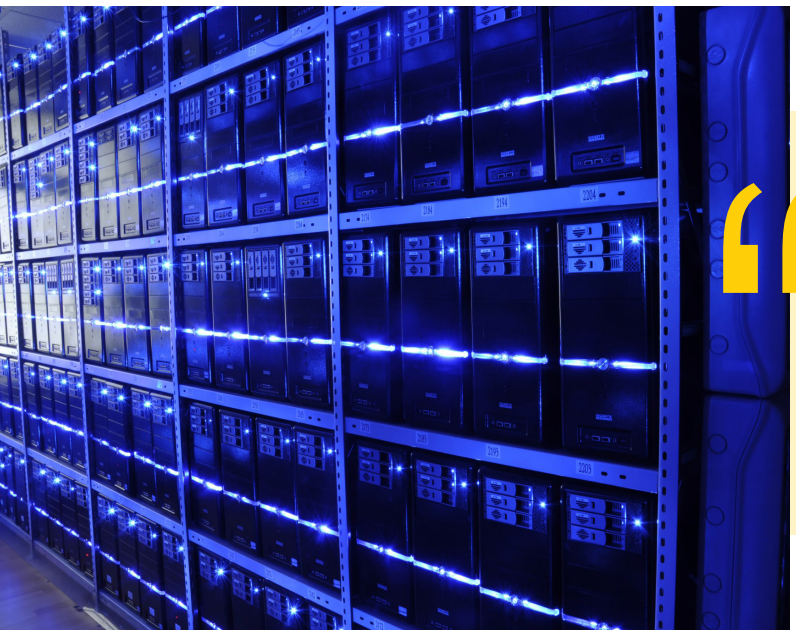
- Set strategic goals for learning objectives and alumni outcomes, and develop processes for tracking and evaluating outcomes. This may include benchmarking against peer programs.
- Work with other STEM-in-Society programs through conference convenings and other means to share best practices, challenges, and potential inter-university collaborations.
- Take advantage of opportunities to connect with the leaders of STEM programs and explain STEM-in-Society and its value, particularly for ensuring diversity, equity, inclusion, and justice in STEM.

Introduction

The centrality of science and technology in our daily lives makes socially responsible research and ethical innovation increasingly important. We need leaders—including STEM experts[3]—who understand the intersections between scientific developments, technologies, and society and have the skills to influence public policies.[4]

However, most budding scientists, engineers, policymakers, and other professionals are trained in narrow disciplines and lack the skills needed to assess the societal risks and costs of emerging scientific tools or technologies; further, the majority of STEM experts don't understand the policymaking environment.[5] This limits efforts to develop technologies or policies that are socially beneficial and environmentally sustainable. Higher education programs that integrate human context and social science insights into STEM training are essential for preparing a workforce that is equipped to address technosocial problems.

Research funders are addressing the need for more responsible scientists and engineers by requiring grant recipients to include public engagement and social considerations in their research. The National Science Foundation (NSF), for example, requires grantees to incorporate broader social impacts into NSF-funded scientific research projects. Introduced in 1997, NSF's



> "STEM education must prepare our workforce to innovate and work with modern technologies, and also to consider their societal effects."[6]

"Broader Impacts Criterion" emphasizes "tangible benefits to society that go beyond increasing knowledge."[7] While requirements like this are important, they fail to acknowledge that even well-intentioned scientists and engineers often "assume rather than investigate who makes up the publics of their research, and what they want (or need) from science and technology."[8] STEM researchers often add proposed "broader impacts" to fully formed projects without first identifying potential stakeholders or exploring the broader social implications of their work. [9]

The Ford Foundation has a "Technology and Society Strategy" that emphasizes public interest technology and building "just and equitable internet and digital technologies, designed and governed to protect and advance social and economic justice,"[10] and the Kavli Foundation has a "Science and Society" arm that goes beyond funding STEM research by "ensuring the people, processes and products of basic science contribute meaningfully to society."[11] This includes funding public engagement in science initiatives, including two university-based Kavli Centers for Ethics, Science, and the Public. The NSF began funding technology innovation projects that incorporate partnerships between researchers and communities in 2022,[12] and more recently established the Responsible Design, Development, and Deployment of Technologies (ReDDDoT) program which "aims to ensure that ethical, legal, and societal considerations and community values are embedded across technology lifecycles to generate products that promote the public's wellbeing and mitigate harm."[13] However, the outcomes and benefits of these programs are either understudied or will need to be assessed in the future.

The reality is that traditional higher education training does not prepare scientists and engineers to work at the intersections of science, technology, society, and public policy. Taking an active role in public policy, for instance, requires STEM experts to acquire more than specialized research skills. It requires a sophisticated understanding of how governments and policymaking function and the ability to communicate scientific evidence in an understandable, respectful, and succinct way so that non-scientists, including policymakers, can readily access the information they need to make informed decisions.[14]

Fortunately, STEM-in-Society programs have been providing this training for decades. We define a STEM-in-Society program as any undergraduate or graduate degree, minor, or certificate program that emphasizes how science, technology, engineering, or medicine intersect with ethics, policy, or society. This intentionally broad definition includes programs in bioethics, engineering policy, science and technology studies, and science and technology policy, but was not limited to programs with these exact titles.[15] Such programs use analytical lenses from the social sciences and humanities to understand STEM fields in social and historical context, as well as the complex impacts of STEM research and technology on communities and individuals. Science and technology studies (STS) programs, for example, have provided undergraduate and graduate education for over 50 years. Bioethics is similar to STS in its multidisciplinarity but focuses specifically on the ethical and moral issues associated with biomedical research, public health medicine, and related technologies. Science and technology policy (STP) programs focus on the laws, regulations, and research funding as they relate to scientific research and new or

existing technologies. Other fields, like public interest technology, have grown in popularity and proliferated in the past five years.[16] By drawing from multiple disciplines and analytical approaches, each of these fields offers students the ability to think and work across disciplines and engage in complex problem-solving, policymaking, and ethical decision making.

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While emerging professionals are increasingly interested in STEM-in-Society training to tackle contemporary science and technology challenges, these programs face numerous challenges. Some, including decreasing funding and declining enrollment, are ubiquitous across higher education institutions regardless of the field of study. But STEM-in-Society programs' interdisciplinary nature often makes typical higher education challenges more acute. Single-discipline programs are well-established within their respective academic institutions, whereas STEM-in-Society programs must constantly evolve to stay relevant in the wake of rapid technological innovation and increased social justice concerns. Newer STEM-in-Society programs lack the alumni base and employment data that long-standing programs use to attract students. These challenges put an added burden on STEM-in-Society program leaders to fundraise, redesign programs, and attract students.

The increasing expectation that science and technology professionals obtain the skills to conduct socially responsible research and innovation and contribute to improving science and technology policies throughout their careers creates a need to better understand the current STEM-in-Society landscape. This report characterizes the current landscape of STEM-in-Society higher education programs in the United States and identifies the challenges and opportunities that arise for graduates, program

STEM-IN-SOCIETY SUBFIELDS

SCIENCE AND TECHNOLOGY STUDIES (STS), also sometimes termed science and technology in society, or science studies, emerged in the 1960s and 1970s primarily in the United States and Europe. STS examines how science and technology are embedded within social systems, and focuses on understanding how scientific knowledge and technological systems impact individuals and communities. STS scholars draw from a range of disciplines, including history, sociology, philosophy, and anthropology, to explore and critique these developments and their relationship to the public interest. One way STS programs reach future scientists and engineers is through undergraduate minor programs that are available to students majoring in a STEM field. Programs like these are intended to help engineers and scientists understand the ethical considerations of their work and related professional responsibilities. They also introduce the utility of using applied interdisciplinary social science methods to study technological and scientific developments.

BIOETHICS is both a field of study and a practice within clinical medicine, medical research, and biological research that focuses on the ethical, social, and legal issues that arise in these settings. Bioethics is both a field of study and a practice. Advances in clinical medicine and biomedical research, coupled with research scandals in the middle of the 20th century, necessitated ethics training for medical professionals and researchers whose work included human subjects or patients. Unregulated, exploratory medicine that included humans as experimental subjects caused harm to individuals and disadvantaged communities. Bioethics thus emerged as a response to a lack of accountability in biomedical research in the 1960s and 1970s. Bioethics higher education programs were initially designed for medical students and practicing healthcare professionals, but some programs are now designed to include biomedical engineers and public health professionals more broadly. Bioethics is also now considered a career path in its own right, with bioethicists being employed by research institutions and medical facilities to serve on ethics review boards.

SCIENCE AND TECHNOLOGY POLICY (STP) emerged in response to an increasing need for specialists who could navigate a period of rapid technological growth in the mid- to late 20th century. Public policy professionals who understand how emergent technologies and scientific research impact communities and individuals' daily lives play an essential role in science and/or technology policy design, implementation, and analysis. Emphasizing this need, the federal Office of Science and Technology Policy (OSTP) was established in 1976 and mandated, in part, to "advise the President and others within the Executive Office of the President on the effects of science and technology on domestic and international affairs."19 Science and technology-focused programs are still relatively new and niche among policy programs, but their importance is growing as technologies like artificial intelligence become ubiquitous across nearly every facet of our daily lives. STP programs are informed by a range of disciplines and analytical approaches, from economics to STS. They have a more direct and focused link to contemporary policy design, implementation, and analysis.

PUBLIC INTEREST TECHNOLOGY (PIT) is a newer field that has emerged over the last decade, which emphasizes using technology—particularly digital technologies, including AI—to serve the public good.20 It is also described as "the study and application of technology expertise to advance the public interest."21 PIT scholars and practitioners draw from numerous disciplines to examine how individuals and communities are impacted by the technologies associated with the many ubiquitous products and services that are embedded in their lives. A key component of PIT is promoting justice and autonomy for publics and in particular those communities that are most at risk of being impacted by the negative consequences of technologies.

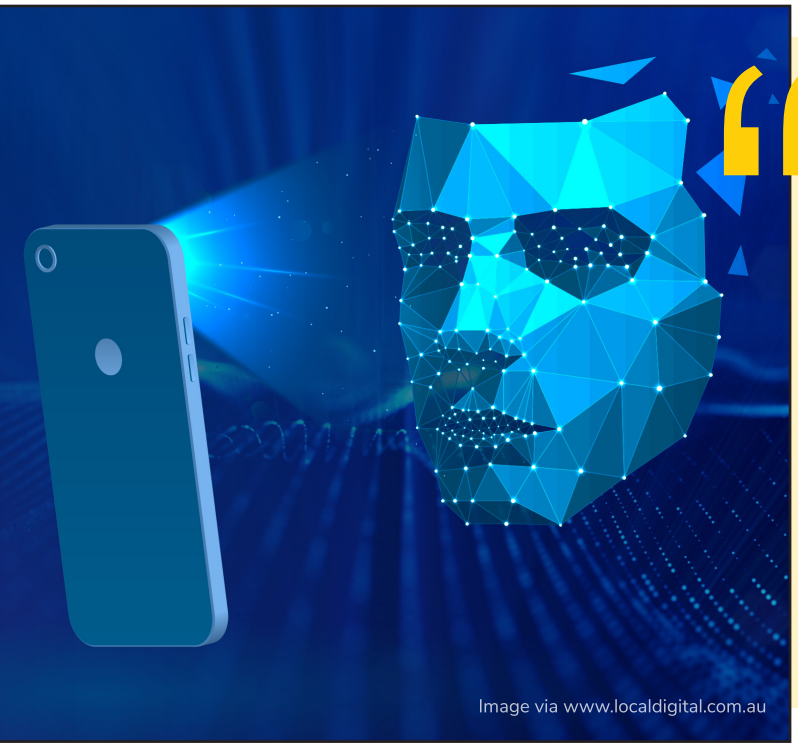


Image via www.localdigital.com.au

> "This report characterizes the current landscape of STEM-in-Society higher education programs in the United States and identifies the challenges and opportunities that arise for graduates, program leaders, university administrators, and funders. We also discern variation across STEM-in-Society programs based on their histories, university contexts, and program structures. The report ends with recommendations to support and sustain such programs."

leaders, university administrators, and funders. We also discern variation across STEM-in-Society programs based on their histories, university contexts, and program structures. The report ends with recommendations to support and sustain such programs.

Research Design Overview

This landscape assessment identifies and describes STEM-in-Society programs in the United States and uses case studies to highlight the unique challenges, needs, and opportunities these programs face. We used a multi-scalar and mixed methods approach to both identify big picture trends and illustrate program-level experiences. By sharing challenges that these programs face, and related solutions, we hope to help university leaders, STEM-in-Society program administrators, and funders identify ideal areas for collaboration and investment.

We began our assessment with a field scan where we identified STEM-in-Society programs within the United States. Field scan data collection included program-level website content and a survey of 78 STEM-in-Society programs. To ground our broad-scale field scan findings in program-level context, we then selected five case studies and one program snapshot; each represents a research center, department, or school that confers at least one STEM-in-Society degree, minor, or certificate. The selected cases represent the breadth of programs identified in our initial scan and collectively include a range of geographic locations, program ages, student audiences, and degree types. Data collection for these included semi-structured interviews with program leaders, faculty, staff, students, and alumni.

Table 1 provides an overview of each data source (including the number of websites, respondents, or interviews), specific types of data collected from each source, and the analysis approaches and tools used to collect and analyze each data source. Program website and interview data were used in combination with literature reviews to inform the case studies. Appendix A provides additional information about our data sources and analysis methods.

TABLE 1. Data sources, data analysis approaches, and tools or software used

DATA SOURCE	DATA COLLECTED	APPROACH	TOOL(S)
STEM-in-Society program websites (n=224)[25]	University type, field of study, learning objectives, curriculum requirements, experiential learning	Summarization and descriptive statistics	Excel Stata
Program survey (n=82)[26]	Program size (enrollment and faculty), program age, admissions requirements, funding sources, year the program was founded.	Summarization and descriptive statistics	Qualtrics Excel Stata
Semi-structured interviews (n=79)	Program leaders, faculty, and staff; Students and alumni	Directed thematic coding	Scribie NVivo

Landscape Scan

HIGHLIGHTS

- **STEM-in-Society programs are well positioned to reach research-oriented STEM undergraduate and graduate students, postdocs, and faculty.** Most (76%) of the institutions that host STEM-in-Society programs are research-centered "R1" universities that grant doctoral degrees.

- **Science, technology, and society (STS) programs have unmeasured and undervalued impacts on undergraduate students.** The majority of STEM-in-Society programs are undergraduate science and technology studies programs that typically reach non-STS majors through general education courses and minor options.

- **STEM-in-Society programs meet students' unique needs and interdisciplinary interests by offering flexible program requirements and formats.** Some undergraduate minor and graduate certificate programs are designed to be completed in tandem with students' primary degree programs. Professional certificate programs provide more flexible learning format options (e.g., online, part-time) than traditional degree programs.

- **Undergraduate STEM-in-Society programs emphasize applied learning opportunities more than graduate-level programs.** Graduate STEM-in-Society programs primarily train students to be academic researchers, whereas undergraduate programs are more likely to require internships or project-based courses that emphasize professional skills.

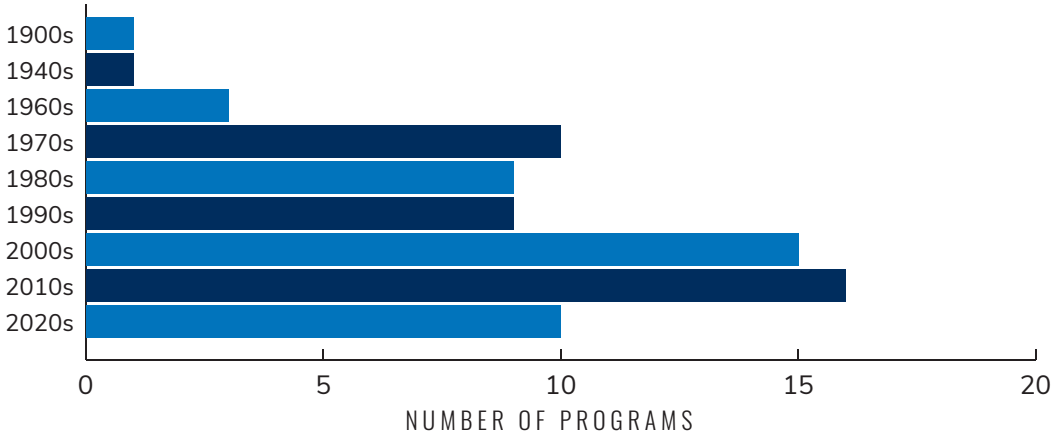
- **Professionals seeking STEM-in-Society training have very few higher education options.** Continuing professional education (CPE) programs, typically certificates available to individuals who are not enrolled in another degree program, are limited in number and typically focus on bioethics or a sub-topic within science and technology policy.

- **Diversity, equity, inclusion, and justice (DEIJ) frameworks are largely missing from STEM-in-Society program curricula and professional development.** Only a handful of programs position their learning objectives within the context of the intersections of science and/or technology and DEIJ issues.

- **Alumni of STEM-in-Society programs work across a range of professional fields and academic spaces.** This includes faculty positions and research/professional positions in non-profit organizations, public service agencies, industry, and academia.

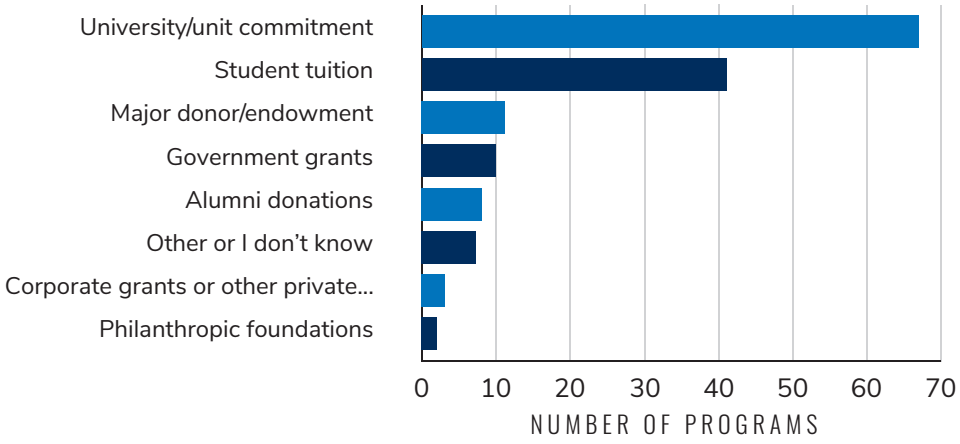
Most STEM-in-Society programs are relatively young, with over 50 percent founded in the past 25 years (Figure 1). From the 1970s to the 1990s, about 10 STEM-in-Society programs were founded per year, but the number increased sharply in the 2000s and 2010s. This trend has continued in recent years. In building these programs, higher education institutions and their faculty may be responding to a number of factors, from increasing media coverage of science and technology issues to demand from students, policymakers, and funders for STEM-in-Society education opportunities.

Figure 1. When STEM-in-Society programs were founded, by decade (n=74)



Most STEM-in-Society education programs (84% of survey respondents) are financed through a combination of university or administrative unit commitments and student tuition (Figure 2). Most do not benefit from external grants or donations, and only 3–4 percent receive philanthropic funding or private sector grants, suggesting an area of potential growth. Instead, degree programs are largely self-sustaining through student tuition fees and university support for faculty salaries.

Figure 2. STEM-in-Society program funding sources (n=80)



STEM-in-Society programs may be able to diversify their funding sources by seeking major donors/endowments, government grants, and alumni donations. However, many lack the capacity to pursue external funding sources or initiate relationships with private donors and funders, and university administrators (and development offices) do not treat them as priorities. Without dedicated attention or resources, it is difficult to pursue new funding opportunities. To make matters more challenging, our interviews suggest that program leaders spend a good deal of time simply maintaining on-campus relationships and justifying their STEM-in-Society program to administrators. This takes time away from building relationships with foundations or pursuing private funding sources.

Measuring faculty size proved challenging because STEM-in-Society programs each define faculty roles in different ways. In some instances, faculty are in affiliate roles, and their contributions to core education activities is unclear. We attempted to address this challenge by asking survey respondents, "How many faculty are actively engaged in this STEM-in-Society program throughout the academic year?" which we defined as, "active engagement includes teaching courses, leading experiential learning opportunities, participating in program events, and supervising student researchers." STEM-in-Society programs with 11–24 faculty engaged in one or more of those activities were the most common. However, we did not specifically ask how many faculty (or staff) lead core programmatic activities such as designing learning objectives, hiring faculty and/or staff, vetting and admitting students, or fundraising, which likely rely on a much smaller number of people to carry out.

Who Do STEM-in-Society Programs Serve?

STEM-in-Society programs are poised to reach the researchers of the future. Most are based at R1 schools; we identified 90 institutions that host a total of 246 STEM-in-Society programs in the United States, and the majority (76 percent) were at R1 institutions.[27] These programs have a large potential pool of students, postdoctoral scholars, and faculty members who could benefit from STEM-in-Society training, but have historically struggled to fully reach these audiences. In contrast, fewer STEM-in-Society programs are located at R2, liberal arts, or minority-serving institutions.[28]

Among universities that do have STEM-in-Society programs, the majority (65%) offer multiple programs administered by different departments, schools, or research centers. Georgia Institute of Technology, for example, has a total of seven STEM-in-Society programs offered by four different campus units (Public Policy; History and Sociology; Literature, Media, and Communication; and International Affairs). Where these programs are housed also varies by field of study. Bioethics programs are typically administered by a bioethics-specific research center or institute, whereas STS programs are found within a mix of larger campus units (e.g., a liberal arts college);

specialized departments (e.g., history, science and technology studies, or sociology); and cross-disciplinary programs co-led by faculty from different departments or colleges. STP programs typically appear within Schools of Public Affairs, Policy, or Government. Program diversity has pros and cons. It enables students to find the degree or certificate that best suits their needs but also requires programs to have a clear program identity, learning objectives, and alumni outcomes so they can attract prospective students and compete with peer programs. However, multiple distinct STEM-in-Society programs across the same campus can make it harder to build collaborations with STEM researchers or be easily identified by potential funders who need to quickly discern their unique expertise.

We divided STEM-in-Society programs into six categories based on their primary learning objectives. Science and technology studies programs dominate the STEM-in-Society landscape, making up over half (56%) of all STEM-in-Society programs, followed by ethics programs (Figure 3). The three least common fields of study were public interest technology, engineering and policy, and specific topics within science and technology policy. To identify whom STEM-in-Society programs are serving, we subdivided each field of study into their respective audiences. With the exception of STS programs, which primarily offer undergraduate major and minor programs, all fields of study primarily serve graduate students (Figure 4).

But student populations vary in their interests. Some may be master's students in public policy interested in the regulation of emerging technologies like AI. Others may be STEM graduate students confronting new ethical questions in their research or curious about pursuing a science and technology policy career. The traditional pathway for newly minted PhDs has been to remain in academia and become a research or teaching professor or some combination of the two. However, attractive academic positions are scarce, and the job market is highly competitive. STEM-in-Society programs can fill the void of non-academic career assistance that currently exists in higher education by helping graduate students understand how to transfer their knowledge and skill sets into non-academic careers. For example, the Science Policy and Advocacy Certificate Program at the University of California, Irvine helps graduate students and postdoctoral trainees acquire essential science policy career skills and prepares them to pursue careers outside of academia.

Figure 3. STEM-in-Society Programs by Field of Study (% out of 246 programs)

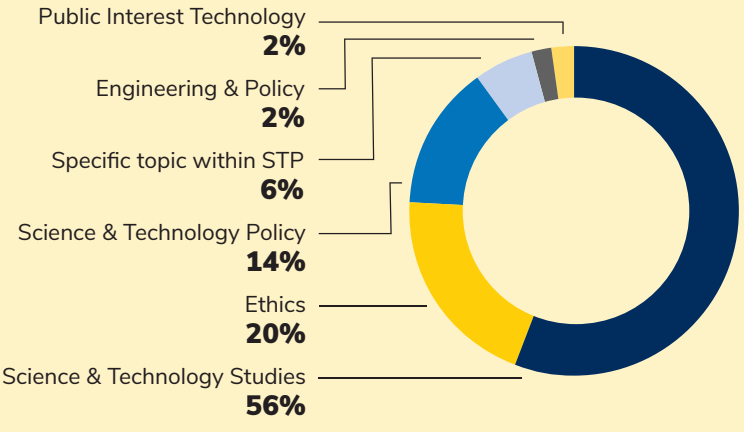
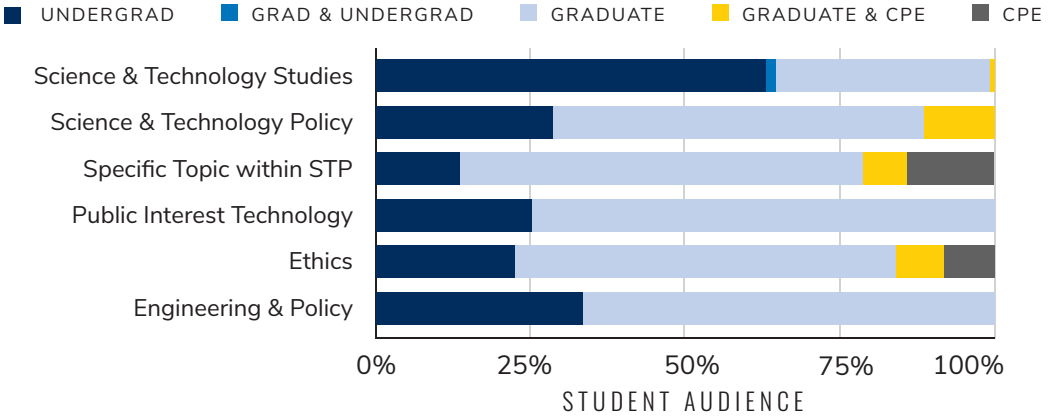


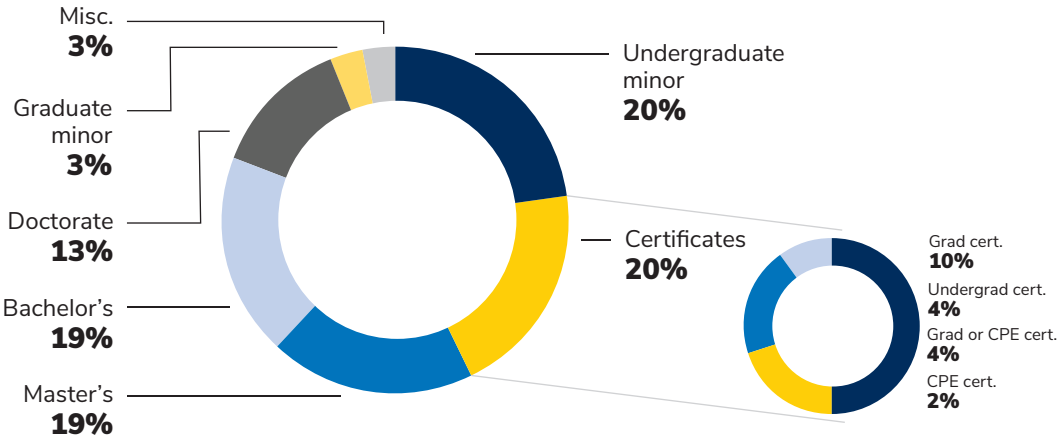
Figure 4. Distribution of Student Audiences by Field of Study



Expanding undergraduate training in STP, PIT, ethics, and engineering and policy could provide pre-professional undergraduate training and address the increasing demand for responsible research and innovation. Undergraduate minors in particular could reach students across STEM majors and typically add minimal additional coursework. For example, in schools with large engineering programs, STEM-in-Society programs could expand their footprints by offering an STP or engineering ethics minor. Such undergraduate opportunities could help STEM-in-Society programs build broader awareness of their degree options and increase funding through increased enrollment.

STEM-in-Society programs are evenly distributed between undergraduate and graduate audiences (Figure 5), but only 6% (16 programs) are available to individuals seeking continuing professional education (CPE). The scarcity of CPE programs could reflect a lack of demand or lack of funding

Figure 5. STEM-in-Society Programs by Student Audience
(% of 246 programs)



support for such training, but growing awareness of the social and policy challenges associated with science and technology increases the importance of such training.

Existing CPE training options tend to be highly specialized, focusing either on a narrow topic within science and technology policy or bioethics. The online certificate in "Cybersecurity, Technology and Policy" offered by Florida International University, for instance, is marketed to public and private sector leaders who are already working in this field.[29] Programs like these help professionals update their knowledge in a specific issue area and become specialized.

However, designing new programs requires substantial investments of effort and time, and implementing new degree or certificate programs requires navigating university and state-level oversight and approval requirements. Because trends in science and technology shift rapidly, it can be difficult to quickly develop high-quality, truly multidisciplinary programs that are both responsive and useful. Instead of building new programs from the ground-up, current graduate certificate programs may be better positioned to expand their offerings to professionals by pivoting their learning objectives, adding new classes, leveraging online learning options, and/or hiring faculty with specific expertise.

Program Flexibility is Essential in a Shifting Landscape

STEM-in-Society programs attract students with unique interests, learning needs, and financial means by delivering programs in multiple learning formats, providing different tracks and timelines for completing program requirements, and allowing students to pursue their own topic(s) of interest. Eight of the 16 continuing professional education programs we identified accommodate working professionals and distance learners by offering online, hybrid, evening, and part-time options. Many in-person and hybrid format CPE programs were primarily located in Washington, D.C., Virginia, and Maryland and target working professionals in the D.C. Metropolitan region. Carnegie Mellon University markets a new PIT certificate to government employees and future civic leaders and caters to these audiences by offering both hybrid and fully online options. The online program does include synchronous learning so students can build connections with their cohorts and participate in meaningful course discussions.

Professionals with time or financial constraints benefit from flexible completion timelines and stand-alone course options. Florida International University's Cybersecurity, Technology and Policy certificate, for example, consists of a series of short courses covering specific topics and skills like "Cybersecurity Leadership and Strategy," "Artificial Intelligence and Governance," and "Information Landscape and Policy." Each course is available as a stand-alone learning option so students can balance continuing education with other commitments. This approach also relieves some of the financial burden of completing a comprehensive program by allowing students to enroll part-time and cover program costs

piecewise and at a pace that works best for them. Similarly, Loyola Marymount University gives bioethics certificate students the option to transfer into the bioethics master's program by counting certificate course credits towards the completion of a master's degree. In this way, certificate and degree programs can work together to encourage prospective students to begin with the certificate program and then decide if they want to pursue a master's degree.

Undergraduate STEM-in-Society programs streamline degree requirements to attract students who already have a primary major. Minor and certificate programs, for instance, can design their courses to meet university-level liberal arts or general studies requirements that apply to all students regardless of major. This allows students to add a STEM-in-Society credential to their major without adding additional courses to their schedule. For example, the Integrated Studies in Science, Engineering, and Society Undergraduate (ISSuES) Certificate Program at the University of Wisconsin–Madison gives students the opportunity to explore the intersections of STEM and society while simultaneously fulfilling university-level liberal arts requirements.

Providing topical flexibility is important because students' interests shift as science and technology issues evolve, and STEM-in-Society programs must find ways to serve students who have a range of their own prior expertise, current interests, and future career goals. Some programs address this by encouraging students to customize their studies by selecting courses from a list of options or taking courses through other programs. The University of Michigan's Science, Technology, and Public Policy graduate certificate program encourages students to select courses from a long list of approved electives so they can tailor their certificate experience to their academic interests and/or career goals.[30] Other programs allow students to select both their own research (or capstone project) topic and the format of their final product. Students in the Global Technology and Development master's program at Arizona State University can choose from a number of applied project formats:

> There is some flexibility and scope in the nature of each student's Applied Project. It can be a research paper where students must introduce a research problem, conduct a relevant literature review, describe the methodology, and then conduct research or create a project to solve that problem. Students will evaluate the research results or the project in a written document. There is also room for various other options, including a research proposal for funding, a publishable paper, or a multimedia project such as a film documentary or other audiovisual exploration and demonstration of concepts, research and development practices.[31]

Providing topical flexibility is especially important when programs lack expertise in students' field of interest. STEM-in-Society programs cannot maintain faculty expertise in every emergent technological innovation and science topic or problem. Carnegie Mellon's Engineering and Public Policy program encourages PhD students to seek research mentorship from faculty outside their home department. In this way, students can access and benefit from faculty expertise that, due to the interdisciplinarity of STEM-in-Society topics and research, might be distributed across the university more broadly.

Professional Development Through Experiential Learning

College students are increasingly seeking professional skills and applied learning opportunities to improve their competitiveness on the job market.[32] The experiential learning that STEM-in-Society programs provide differ by student audience.[33] Many undergraduate programs incorporate professional internships that facilitate career networking opportunities and capstone experiences, completed at the end of a student's degree program, that may include an individual senior thesis or group project. Capstones can be particularly powerful by giving students the opportunity to apply multidisciplinary methods to address a real-world technological question or science issue. For example, the Science, Technology, Ethics and Policy (STEP) undergraduate minor at the University of Maryland requires students to apply the knowledge gained in STEP courses to complete a culminating capstone course project that incorporates research and communication skills.

> This course focuses on applying concepts and building on knowledge obtained in the STEP minor course work and should be taken as the last in a student's minor sequence. Students will use interdisciplinary methods from the social sciences and humanities to gain a better understanding of the political, ethical, social, environmental, cultural, economic, and technical complexities of science and technology. They will learn how to formulate a good question, employ several data collection methods (literature review, interviews, natural observation, document analysis) to gather evidence that supports the thesis, and apply a conceptual framework that gives the project coherence. Along the way, as a way to receive feedback to improve their study, students will give several types of professional presentations (posters, oral presentations, facilitated discussion) of their research progress.[34]

However, our data on experiential learning opportunities is limited since this information was largely omitted from program websites. Additional study of the impact of STEM-in-Society internships, capstone projects, research assistantships, and fellowships on graduates' careers would provide useful insight into how programs can better support students' professional development.

In contrast, graduate-level STEM-in-Society programs typically prepare students for academic careers by emphasizing independent scholarly research skills. For instance, although graduate students may have opportunities to present their research, it is typically for a niche expert audience at academic conferences, department seminars, or a classroom setting. Few programs train students to present their work to public or policy audiences such as government agencies or community organizations or provide experiential learning opportunities. The University of California, Irvine's Science Policy graduate certificate program brings students, postdocs, and policy professionals together to create a podcast series, and the University of California, Santa Cruz's Science and Justice Training Program requires students to produce a public event or workshop

on a science and justice topic of collective concern. The Engineering Law and Policy MS program at Pennsylvania State University ends with a practicum course that grows students' analytical skills while they address a contemporary technology policy issue.

> In this class, we bridge technology theory with technology policy practice. We begin the semester by asking the "big" normative questions of innovation: what kinds of technology are we building? What engineering and ethical principles are we applying? Is this "progress"? How is law helping (or not helping)? Next, using case studies of "hot topics" in technology policy, we apply these ideas to current debates. Finally, through the development of an interdisciplinary team project, [...] engineering students will apply and integrate their knowledge on strategic science and technology policy, regulatory concepts, and systems thinking to the real world policy issue chosen for the team project. The projects are tailored to meet the current research needs of particular federal and state lawmakers and agencies based on their legislative and regulatory agendas for the year. Students will analyze technology and policy options and conceive, design, and execute a technology and policy research project, taking into consideration the political, social, and institutional context of technological systems. The deliverables of the course will be a formal oral presentation of the team project, a public-facing technology tool, and a policy research paper written for relevant policymakers, seeking to assist them in their policy decision-making process. This will require students to reconcile the engineering and technical realities and constraints of the projects as well as the legal implications, stepping into the shoes of a policymaker. Possible policy coverage and project areas include connected health; consumer/ investor protection in security and privacy; disinformation, governance, and tech literacy; internet availability and net neutrality; sustainability and ethics in computing design; the Internet of Things and the right to repair; machine learning/ AI suitability; tech competition; computing history; and tech workforce development.[35]

Students also benefit from low-commitment, informal learning opportunities such as seminars and networking events that offer an informal space to share research and network with academics, policymakers, and professionals working on current STEM-in-Society issues. Domestic travel and study abroad programs can give students a broader, global, and more diverse perspective, including opportunities to learn about diplomacy and international technology policy negotiation and to interact with policymakers, agencies, and other organizations working on science and technology issues. These examples are in the minority, however, demonstrating the need for STEM-in-Society graduate programs to evaluate how they can better serve both early career researchers and students seeking non-academic careers. Students planning to stay in research need guidance on how to conduct more responsible research, and in general, students need skills they can use in a variety of professional settings regardless of their career goals.

Lack of DEIJ in STEM-in-Society Programming

Technological innovations can have disparate impacts, especially on marginalized communities, and STEM-in-Society programs are uniquely positioned to provide training about the connections between STEM and DEIJ. This could also attract a more diverse group of students and provide students from marginalized communities with the tools to bring DEIJ considerations into their STEM education and careers.

However, diversity, equity, inclusion, and justice were largely omitted from STEM-in-Society program websites. Only 34 programs (14% of the landscape) had any mention of DEIJ at all, and even fewer programs (less than 3%) listed DEIJ-specific courses on their websites.[36] Although this information may simply be hidden from the websites, it certainly suggests that these issues are not a priority, or program leaders do not feel comfortable advertising these commitments. This is a missed opportunity, particularly for attracting STEM students from marginalized backgrounds. At best, students in these programs may have to pursue DEIJ-related learning opportunities through elective coursework, independent study, or other activities, which may be a barrier to students who do not have access to these opportunities or the ability to pursue co-curricular activities outside of core program requirements.

Among programs that did advertise a DEIJ component, some mention race, gender, disability, human rights, or justice in a comprehensive list of study topics without providing additional context.[37] Other programs provide vague or boilerplate diversity statements (e.g., "our program is committed to diversity and inclusivity;"[38] or "from its founding, Nazareth has been committed to social justice, has continually evolved to address societal/community needs, and challenges students to be innovators and changemakers."[39]). These don't describe specific activities or steps the program is taking to implement their commitments. A few exceptions were programs that focused on gender or justice. Virginia Tech, for example, offers an undergraduate minor in "Gender, Science and Technology" that draws from expertise in both the STS Department and a Women's and Gender Studies Program.

> By combining classes from the women's and gender studies program and the Science, Technology and Society Department, students will learn to question many of the assumptions that employers, politicians, schools, and scientists hold about gender.[40]

Our case studies were designed to uncover some of these details through student and alumni interviews where we could ask questions about their specific learning experiences.

Two undergraduate programs provided more detailed descriptions of how race and human rights are part of their curricula. The University of California, Berkeley offers a Sciences and Society course "thread" (equivalent to an undergraduate certificate) that "encourages Berkeley undergraduates to consider such topics as the histories and futures of artificial intelligence; race, identity, and genetics; the politics of access to medicines and medical technologies; and global environmental politics, social justice,

and sustainable development." Similarly, the Technology, Artificial Intelligence, and Society BA program at Nazareth University linked disability and technology and described its course content as including "Considerations of race, class, gender/gender identity, sexual orientation, and disability in the use of technology, such as: How can bias be avoided in facial recognition software?"[42] Interestingly, only the University of San Francisco's History of Health Science graduate program mentioned disability in reference to providing access to graduate students with disabilities and offering reasonable accommodations when requested.[43]

Three other programs stood out as exceptions because their learning objectives and curriculum center entirely on social justice and related ethical considerations. The Science and Justice Training Program (SJTP) at the University of California, Santa Cruz's (UC Santa Cruz) Science and Justice Research Center, is the only program with "justice" in its title. This program teaches "students real-life strategies for exploring the meeting of questions of science and knowledge with questions of ethics and justice" and is "unique in its effort to broaden the scope of ethics education in science and engineering to include and build new sites and practices for pursuing social justice."[44] The University of Texas–Rio Grande Valley, also a minority-serving institution, stood out for its online bioethics master's degree program's emphasis on social justice and health equity.[45] This includes related coursework and a required capstone project that "allows the student to conduct an in-depth analysis or empirical research study on a topic of interest" and analyze "a specific bioethical problem with implications for health equity and social justice."[46] And lastly, Georgia Tech's STS graduate certificate program incorporates justice into its program learning objectives and coursework (including research design courses). Students are expected to "Develop sensitivity to issues of gender, race, and justice across areas of knowledge, including: engineering, medicine, environment, cognition, security, innovation, design;" related courses include "Social Justice, Critical Theory and Philosophy of Design," and "Social Justice and Design."[47]

These findings demonstrate the potential for STEM-in-Society programs to grow across multiple dimensions of DEIJ, including expanding DEIJ-related fields of study, creating or supporting pathways for students to learn and apply DEIJ-related STEM-in-Society knowledge and skills in laboratory and other real-world contexts, and creating more welcoming learning environments for students with disabilities.

Career Outcomes for STEM-in-Society Graduates

While tracking alumni career outcomes is essential for attracting prospective students and justifying these programs to university leadership and funders, most STEM-in-Society programs do not make this information publicly available on their websites. Instead, they focus broadly on how their training can improve students' job prospects by giving them the necessary skills to solve

technosocial problems and work at the forefront of scientific and technological innovation in a wide array of jobs.

> Students completing the EPPST minor will gain important skills for creating, proposing, promoting and evaluating policies that respond to the profound challenges and choices we face related to science and technology in the 21st century at local, national and international levels.[48]

> No matter what your major is, the Science, Technology, and Innovation for Global Development Certificate conveys strategic thinking skills, empathy toward practice, and cross-cultural competency that is needed in all industries—including, business, government, the non-profit sector, and academia.[49]

Several programs emphasize that they train students to work across professional silos to address emerging challenges. Communication skills and strategic/critical thinking were typically mentioned as essential interdisciplinary or cross-sector competencies. Seventeen programs stated that they provide the necessary training required for professionals entering new fields and addressing complex problems at the intersection of technology and society.

> After completing this master's in global technology and development, you'll be an ideal candidate for various roles that focus on interpreting technological advancements in society. You may choose to work for private businesses or in public sector roles within government agencies or nonprofit organizations. You'll also be prepared to work in research with your understanding of socioeconomic and political implications of technological development.[50]

Only six programs identified specific organizations where their alumni now work. Graduates of the University of Minnesota's Science, Technology, and Environmental Policy master's program hold a range of public service, private sector, and non-profit positions including: Environmental Impact Manager (U.S. Department of Energy National Renewable Energy Lab), Water Policy Planner (Minnesota Environmental Quality Board), Sustainability Program Coordinator (City of Minneapolis), Research Consultant (International Water Management Institute), Regulatory Affairs Associate (3M), Environmental Specialist (Barr Engineering), and Program and Policy Manager (Center for Energy and the Environment).

> Our alumni have gone on to professional careers across a variety of fields—from teaching history at the college and university level to working in the private sector or as independent scholars.[51]

The lack of specificity could be due to the fact that STEM-in-Society programs are often an add-on to a student's major degree, and alumni therefore end up in a variety of professional roles and sectors. Alternatively, these programs may not have a large pool of alumni to draw from, particularly because these programs are relatively new. Tracking alumni outcomes is also challenging for smaller, interdisciplinary higher education programs that often lack both general staff capacity and access to dedicated career services staff with appropriate training and knowledge of emergent STEM-in-Society careers. Our case studies aim to fill this information gap through alumni interviews at a handful of programs.

Case Studies

Overview

We used five case studies and one truncated program snapshot to understand the impacts of STEM-in-Society programs, illustrate the common challenges and opportunities these programs navigate, and highlight how these vary based on each program's unique goals, history, and university context.[52]

We found that STEM-in-Society programs can prepare students to be responsible researchers by supplementing traditional STEM training with conceptual and analytical skills drawn from the social sciences. They also have long-term institutional and cultural impacts that extend beyond individual learning outcomes. Their faculty, students, alumni, and publications are helping to transform STEM fields while also providing crucial expertise on science and technology in the public interest to policymakers, advocacy organizations, and citizens.

Increasing public attention to STEM-in-Society questions such as technology governance and equitable medical research has brought new funding opportunities and institutional support and challenges such as managing capacity and cultivating leadership pipelines.

Cases were selected to represent a mix of campus units that confer one or more STEM-in-Society credential(s) including certificates, minors, and undergraduate and graduate degrees (both master's and doctorate). We also deliberately selected programs with different emphases including science and technology studies, science and technology policy, and science justice. Three cases offer a mix of undergraduate and graduate education programs, and three only offer graduate-level training. Each university and program, along with its student audience(s), and degrees offered during the 2023-2024 school year are listed in Table 2.

Multiple Definitions of Interdisciplinarity

Although each case prioritizes interdisciplinarity, it is defined differently by each program. This reflects how the definition of interdisciplinary varies within different fields of study. For instance, some programs define interdisciplinarity as using multiple social sciences to train STEM-in-Society students, while others fully integrate STEM fields with social sciences, arts, and humanities in their student training programs. Virginia Tech's

TABLE 2. Case study overview including higher education institute, case study unit of analysis, student audience(s), and education programs offered during 2023-2024 school year.

UNIVERSITY AND UNIT	CASE STUDY	FOUNDED	STUDENT AUDIENCE(S)	DEGREES OFFERED
Carnegie Mellon University College of Engineering	Department of Engineering and Public Policy	1970s	Undergraduate	Additional Major
			Graduate	MS, PhD
Virginia Tech College of Liberal Arts and Human Sciences	Department of Science and Technology Studies	1980s	Undergraduate	Minor
			Graduate	Certificate, MS, PhD
University of Wisconsin—Madison Neuroscience Training Program and the La Follette School of Public Affairs	Neuroscience and Public Policy Program	2004	Graduate	Dual PhD and MPA, Dual PhD and MIPA, Dual PhD and JD
University of Michigan Gerald R. Ford School of Public Policy	Science and Technology Policy Program	2006	Graduate	Certificate
University of California, Santa Cruz	Science and Justice Research Center	2011-2012	Graduate	Certificate
Arizona State University	School for the Future of Innovation in Society	2015	Undergraduate	Certificate, Minor, BA, BS
			Graduate	Certificate, MS, PhD

Department of Science, Technology, and Society (Virginia Tech STS), for instance, primarily focuses on using different social sciences to train students; this includes, but is not limited to, history, policy, and science communication. In contrast, the Department of Engineering and Public Policy (EPP) at Carnegie Mellon University asks engineers to combine social science and policy analysis tools with their technical skills to design potential solutions to engineering problems. Taking this a step further, the Science and Justice Research Center (SJRC) at the University of California, Santa Cruz (UC Santa Cruz) brings STEM, arts, humanities, and social science graduate students together in interdisciplinary teams to design a public-facing research project that fully integrates science justice questions and contemporary science and technology research questions. These differences can create difficulties articulating the value of these programs and communication gaps between STEM-in-Society programs, students, employers, and funders.

Administrative and University Context Varies

Each case's unique context, and organizational culture directly influences its available resources and opportunities. STEM-in-Society programs that are institutionalized within their university can build and maintain program longevity, and cases with sustained leadership—typically from a founding faculty member—have had more stability and are well-positioned to expand.

The School for the Future of Innovation in Society (SFIS) at Arizona State University (ASU), for instance, has direct and consistent ties to university leadership, which enabled earlier iterations of SFIS to later become a fully-fledged school. EPP and Virginia Tech STS are both stand-alone departments that can use typical tenure track hiring practices to maintain faculty and leadership pipelines and benefit from relative stability within their respective universities. Three cases—the SJRC, EPP, and the Science, Technology, and Public Policy Program (STPP) at the University of Michigan—have had consistent leadership from program founders who have dedicated a lot of energy to designing, growing, and sustaining their respective programs. This has given these programs consistency and the opportunity to grow. However, both STPP and the SJRC are independent research centers, which presents challenges in terms of their ability to fully integrate into their respective campuses and opportunities in the form of flexibility to pursue different funding streams.

Where STEM-in-Society programs are situated also directly determines their curriculum and pedagogical approaches. EPP sits within a College of Engineering, and its programs were designed to supplement engineering majors' technical degrees and offer a unique graduate curriculum for individuals seeking to integrate their technical expertise with social assessment skills. In contrast, Virginia Tech STS is housed in a College of Liberal Arts and Human Sciences, and its degree programs draw on different liberal arts fields including history, sociology, and political science. STPP is based within U-M's Ford School of Public Policy, and its graduate certificate program offers introductory policy training to all graduate students regardless of their primary field of study. In this way, some STEM-in-Society programs reach a wider disciplinary range of students and support their ability to transfer into policy-related careers or become more responsible and socially-informed STEM researchers.

Student Benefits of STEM-in-Society Training

STEM-in-Society programs can prepare students to be responsible researchers by supplementing traditional STEM training with conceptual and analytical skills drawn from multiple social sciences, including science and technology studies, ethics, and public policy. Certificate programs like those offered by U-M and UC Santa Cruz offer graduate students from any degree program an accessible credential with a manageable time commitment that both broadens their career options and prepares and motivates them to conduct more responsible STEM research or technology development. These programs also provide students with professional development and career coaching in policy and non-STEM fields that their home departments can't offer. This training introduces students to new professional options and broadens their career options.

Two other cases exemplify how more intensive, dual degree STEM-in-Society programs prepare STEM majors to advance in their careers or explore new opportunities. EPP's additional major program enables undergraduates to supplement their primary engineering degree with additional training in applied problem-solving, group work, and social analysis of engineering problems. This immediately improves their employability and makes them stand out among their peers who do not have this additional training. The University of Wisconsin–Madison's (UW–Madison) Neuroscience and Public Policy Program (N&PP) combines doctoral-level neuroscience training with a public administration or law degree. This intensive program reaches prospective students who know, before entering graduate school, that they want to pursue a STEM-in-Society career or pursue more responsible neuroscience research.

Broader Impacts of STEM-in-Society Programs

STEM-in-Society programs have long-term institutional and cultural impacts that extend beyond individual learning outcomes. Their faculty, students, alumni, and publications are transforming STEM fields and providing crucial expertise on science and technology in the public interest to policymakers, advocacy organizations, and citizens. Alumni often credit these programs with shaping or enabling their careers and creating valuable alumni networks that increase professional development and shared learning opportunities for alumni and current and future students. With faculty and staff mentorship, STPP students produce policy memos and technology assessment reports that policymakers and community organizations rely on for current information on emerging technologies. The SJRC leads university change by demonstrating the benefits of interdisciplinary collaboration and justice-centered public engagement.

As Virginia Tech STS and SFIS demonstrate, STEM-and-Society programs also provide broader university service in the form of designing and teaching undergraduate general elective courses. These courses are important options for both undergraduate and graduate students to have and can also lead to shifts in their academic and professional pursuits. Unfortunately, and despite filling this role on their respective campuses, these efforts are often unrecognized and do not result in increased funding or get taken into account by annual enrollment metrics.

"STEM-in-Society programs have long-term institutional and cultural impacts that extend beyond individual learning outcomes. Their faculty, students, alumni, and publications are transforming STEM fields and providing crucial expertise on science and technology in the public interest to policymakers, advocacy organizations, and citizens."

Shared Opportunities and Challenges

NAVIGATING GROWING INTEREST IN STEM-IN-SOCIETY

Increasing attention to STEM-in-Society questions across the world is generating interest among research and education funders and universities. STEM-in-Society programs have a long history of doing this work and are well-positioned to take advantage of this opportunity. Virginia Tech STS faculty, for instance, have worked with STEM faculty to co-design STS-informed courses for STEM majors and participate in interdisciplinary research collaborations. Collaborations like these help broaden STEM learning, which could help students stay in these fields and also diversify them. However, STEM-in-Society programs and experts are often underutilized and viewed as less important in a perceived hierarchy of fields of study. STEM-in-Society experts must carefully navigate these opportunities to avoid becoming tokenized for their expertise or treated as less important than their STEM counterparts. STEM expertise is perceived as more legitimate and central—even to STEM-in-Society questions—than the social scientists and humanists that populate STEM-in-Society programs.

SUSTAINING LEADERSHIP AND NAVIGATING ADMINISTRATIVE CHALLENGES

Where STEM-in-Society programs are situated, including their administrative unit, can determine how stable or precarious they are. While programs that are not institutionalized campus units may have some university support, they cannot generate their own revenues from courses they teach. As a result, they lack flexibility in how they allocate their budgets and are unable to respond to student demand. External funding can help them serve (and even expand) their mission, but the program is at risk of contraction or elimination at the end of each grant period. Programs that cannot hire permanent faculty themselves cannot cultivate a natural pipeline of new leadership. Ultimately, this means that STEM-in-Society programs tend to be under-resourced in terms of leadership, faculty, and staff capacity. On the other hand, programs like STPP and SJRC that are designated research centers maintain some flexibility in terms of how they shape their research agendas, education programs, and funding streams.

INVESTING IN STAFF BUILDS STEM-IN-SOCIETY PROGRAM CAPACITY

Investing in program staffing increases STEM-in-Society programs' capacity to diversify their funding streams and, in turn, better serve students, policymakers, and community members by adding new services to their research and community engagement portfolios. Relatedly, STEM-in-Society programs that are properly resourced can increase their impacts through policy advising and public engagement. Programs shared specific needs ranging from tailored career services for STEM-in-Society graduates, the need to better track and connect with alumni, program evaluation, and fundraising. Student advisors and career services staff who understand and can communicate the value of STEM-in-Society degrees to prospective students are often in short supply.

At the undergraduate level, programs are competing with other, more well-known degree programs that have clear professional outcomes and longer alumni employment track records. This competition is further complicated at

institutions like ASU that focus on recruiting first generation students for whom investing in higher education is a careful decision. SFIS must convince both these students and their parents that an undergraduate STEM-in-Society degree is a worthwhile investment of their time and money, and this is challenging without clear professional tracks or alumni employment data. To remedy this marketing challenge, multiple programs—including SFIS, EPP, and Virginia Tech STS—noted that they recruit undergraduate students through their general education courses that students from a variety of majors take as GE electives.

STEM-IN-SOCIETY GRADUATES NEED SPECIALIZED CAREER SUPPORT

STEM-in-Society programs offer unique training in how to think about and design science, technology, and related public policies to serve the public interest, and graduates work in a variety of professional sectors and roles. While this is an asset for program alumni, it also necessitates providing students with access to specialized career advising. Centralized campus career services are often ill-equipped to provide career advising to students earning interdisciplinary degrees. Faculty advisors are typically untrained in providing professional advice to students who are not seeking graduate education or an academic career path. Cases with dedicated program staff, like STPP and the SJRC, have more capacity to balance faculty responsibilities with staff capacity to mentor students or connect them with appropriate career resources. EPP, STPP, and Virginia Tech STS also leverage alumni networks to introduce students to STEM-in-Society professionals through visiting speaker series and alumni panels. However, both graduate and undergraduate programs across all of our cases noted continued challenges with providing the nuanced professional coaching that STEM-in-Society graduates need.

Approaching the Cases

The case studies and program snapshot are presented based on when they were founded, beginning with the oldest (Virginia Tech STS) and ending with SFIS at ASU. Together, these case studies highlight how STEM-in-Society programs, and the benefits they provide, are influenced by their founding histories, university context, and related organizational cultures. Each case begins with an overview of the respective STEM-in-Society program's founding history and briefly describes its university backdrop, education program size, and main audiences.[53] Cases also include examples of professional development opportunities and career outcomes alumni of each program experience, illustrating how STEM-in-Society programs prepare students to be responsible researchers and interdisciplinary professionals by supplementing traditional STEM training with conceptual and analytical skills drawn from the social sciences. Anonymized interview quotes are provided to share interviewees' specific perspectives and experiences. Each case closes with a discussion of specific challenges and opportunities each respective campus unit navigates while delivering STEM-in-Society training. This provides a comprehensive picture of how STEM-in-Society programs are transforming STEM education, preparing professionals for interdisciplinary careers, and providing crucial expertise on science and technology in the public interest to policymakers, advocacy organizations, and citizens.

CASE STUDY

Department of Engineering and Public Policy at Carnegie Mellon University

HIGHLIGHTS

- The Department of Engineering and Public Policy (EPP) at Carnegie Mellon University is led by, and primarily serves, engineers and technical experts interested in the sociopolitical implications of their work.
- Becoming a department enabled EPP to expand its education offerings and hire tenure-track faculty, which created a built-in pipeline for program leadership.
- Undergraduates can supplement their engineering degree with an additional EPP major that provides group project experience and exploration of real-world problems with embedded socio-technical considerations.
- Early career engineers with both technical and social/policy training are more attractive to job recruiters and can leverage their interdisciplinary skill sets to advance in their careers.
- EPP prepares doctoral students for interdisciplinary roles by requiring them to both maintain and grow their technical expertise and acquire new social science skills.
- EPP is well-positioned to grow its policy engagement activities and integrate this with student professional development and networking opportunities.

History and Institutional Context

The Department of Engineering and Public Policy (EPP) at Carnegie Mellon University highlights a STEM-in-Society program designed by engineering faculty that primarily serves undergraduate

engineering majors and graduate students seeking a combination of technical and social science training. Situated within the College of Engineering at Carnegie Mellon University (Carnegie Mellon or CMU), the Department of Engineering and Public Policy (EPP) is characterized by a history of consistent leadership and a focused educational mission. EPP's degree programs and curricula are heavily influenced by Carnegie Mellon's roots as a vocational school that emphasized applying technical expertise to solve real-world challenges, or as one interviewee said, "policy problems where the technical details matter." Its website explains:

> Humanity's greatest contemporary challenges transcend disciplinary boundaries. Crafting effective policy in domains as diverse as climate change, misinformation, national security, artificial intelligence, natural disaster response, privacy, and critical infrastructures increasingly requires expertise that spans and integrates technical and social science fields. The Department of Engineering and Public Policy (EPP) at Carnegie Mellon University is a unique department that works to solve problems at the interface of science, technology, and society. [...] Our students build skills in policy analysis, risk assessment, data science, and decision-making needed to solve today's complex problems in business, government, and non-profits across the globe.[54]

Carnegie Mellon is a private research university located in Pittsburgh, Pennsylvania. Established in 1900 by Andrew Carnegie as the Carnegie Technical Schools, CMU began to grant four-year degrees as the Carnegie Institute of Technology in 1912. Interdisciplinarity and an emphasis on understanding real-world challenges are baked into its institutional culture. In 2022, student enrollment reached over 16,000 students, split between a slight majority of postgraduates (~8,500) and undergraduate students (~7,500).[55]

Several factors have helped sustain EPP over time. Its early transition from a degree program to a stand-alone department within the College of Engineering institutionalized EEP's education programs and provided the administrative structure and funding to hire tenure-track faculty, expand degree programs and offerings, and serve a greater number of students.

> *The decision to make us an academic department, as opposed to some program that sits between departments or spans departments, has been a good thing because at least every year when I talk to prospective students, I tout that. But I do believe it because there's lots of programs that get invented and with good intentions, like, 'Oh, there's this sort of connection between these two things and we should be addressing it.' But then if it doesn't really have the institutional backing, sometimes it evaporates, it just becomes a website or something like that. So I think the fact that we have a couple of 100 students altogether, we've got 20-ish faculty we can hire, we can*

> *get people through promotion and tenure...all the things that an academic department does, we're empowered to do. The fact that we're a department as opposed to a program or something, I think has been helpful, especially over the long run.* **—FACULTY**

In addition, EPP has had consistent leadership with only two individuals serving as department head. Having a founding leader in place for multiple decades fostered departmental stability, growth, and a steady focus on its core educational mission. It is also common for EPP tenure-track faculty to have joint appointments with other departments, both within and outside the College of Engineering (though the latter is more common), and this creates additional stability. EPP faculty members bring a breadth of technical expertise from a range of engineering disciplines as well as engineering-adjacent fields like computer science. While EPP's faculty do not necessarily have formal policy training, their research typically addresses real-world problems where understanding technical details is necessary to inform industry standards, best practice decisions, and state or federal policies.

Program Size and Audience

EPP prepares students to solve technology-centered policy problems by integrating technical and social analysis training. For much of its history, EPP has served two primary audiences: undergraduates seeking to supplement their engineering degree with interdisciplinary skills they can use to solve real-world problems and STEM-trained graduate students who want to work at the intersection of technical problems and social solutions.

> *We don't try to be a whole, a one-stop shop across all the public policy areas. We focus on things where we feel like engineers have some special contribution. And so we do a lot of energy and environment and climate change and air pollution, but we have growing stuff on computer privacy and security. We're trying to move into online misinformation and governance of AI and some of those kinds of newer areas as well.* **—FACULTY**

We focused our analysis on EPP's two primary degrees: an undergraduate "additional major" that engineering majors can add to their education plan and a PhD program; both were established in the 1970s.[56] More recently, EPP has expanded its offerings to include minors for non-engineering undergraduates and master's degree programs. Table 3 lists each of EPP's degree offerings, the year each was founded, and approximate annual enrollment for each degree program during the 2023-2024 academic year.

TABLE 3. Education programs offered by the Department of Engineering and Public Policy during the 2023-2024 school year.

AUDIENCE	TITLE	DEGREE	FORMAT	YEAR ESTABLISHED	2023-24 ENROLLMENT
Undergraduate	Engineering and Public Policy	Additional Major	in-person	1976*	66
Undergraduate	Science, Technology, and Public Policy	Additional Major	in-person	2014	5
Undergraduate	Technology and Policy Minor	Minor	in-person	1995	1
Undergraduate	Information Security, Privacy and Policy**	Minor	in-person	2020	0
Graduate	Engineering and Public Policy	MS	in-person	2021	12
Graduate	Engineering and Technology Innovation Management	MS	in-person	2007	48
Graduate	Engineering and Public Policy	PhD	in-person	1977***	46

*Year Engineering and Public Policy became a department in the College of Engineering at Carnegie Mellon.

**This minor is offered by both the College of Engineering and the School of Computer Science at Carnegie Mellon.

***Year authorized to award the PhD degree.

Source: Data from the Department of Engineering and Public Policy, Carnegie Mellon University

A Value-Added Degree for Undergraduate Engineering Majors

The EPP additional major is a supplementary degree for undergraduate engineering majors that prepares students to be socially responsible engineers. The program emphasizes problem solving, communication skills, and helping students understand how engineering design projects meant to solve technical problems are inherently tied to public health, safety, cultural, environmental, and economic needs. Programs like this that integrate engineering and public policy are unique within the broader STEM-in-Society program landscape, but they are an effective way to reach engineering majors at the undergraduate level.

> *What are we trying to do here? I think at some level it's helping engineering students recognize the impact that engineering and technology have on society and on policy as well as the reverse, that we play a role in shaping society and policy as much as we*

> *are shaped by it, and our work would be shaped by it. And that having this breadth of skills just allows you to be a leader in that space. And when I say skills, I think some of it is just awareness of the broad scope of problems. But we also put a large emphasis on quantitative decision making methods and qualitative decision making methods that are probably really the core of skills. And the next step of that is then communication. How do we communicate our results well, to various audiences in order to get the change to happen.* **—FACULTY**

To recruit students, EPP designed the additional major to fit into students' primary degree and graduation timeline. By counting EPP courses as electives for their primary degree, students can complete both degrees without extending their graduation timeline. Interviewees cited this streamlined design and the opportunity to work on interdisciplinary group projects as key for attracting prospective students.

> *The first thing that drew me to it was I felt like it was more well rounded than just my primary major. And I really liked the idea of learning about policy and how technology and engineering applications can affect and impact policy. And then also learning how well it incorporated into my primary major and hearing that I didn't have to overload to be able to get the additional major, and then how much overlap there was in all of our classes where I could double count some things was definitely very encouraging to hear.* **— CURRENT STUDENT**

> *I think the interdisciplinary aspect of EPP really drew me...to be able to meet other students in the College of Engineering that we were all interested in policy related things, but we all weren't one major doing the same thing.* **—CURRENT STUDENT**

EPP requires two introductory courses ("Introduction to Engineering and Public Policy'' and "EPP Sophomore Seminar"); five core area courses in microeconomics, statistics, decision science, and writing; three Technology-Policy electives, and capstone courses. Capstone courses introduce interdisciplinary technology policy issues and analytical approaches for addressing the technical and social aspects of real-world technology issues. During "Applied Methods for Technology-Policy Analysis" and two "EPP Projects" courses, students work in small teams to explore different facets of a big, real-world problem.

> *We were looking at an area of Pittsburgh that floods due to poor storm water sewer overflow systems. And one of the groups was looking at, What if we install rain gardens? What if we install this or that, and where could we put them? And how do we, with an emphasis on within the watershed, 4% of the population lives in this place that always gets flooded. We need 96% of the watershed to do some work of implementing technology changes to help them. So making that shift, there's another group of students that looked at the policy aspect. Where can we get federal, state, or local funding? What are other grant programs that we could use to support these families to address when their basements get flooded?* **—FACULTY**

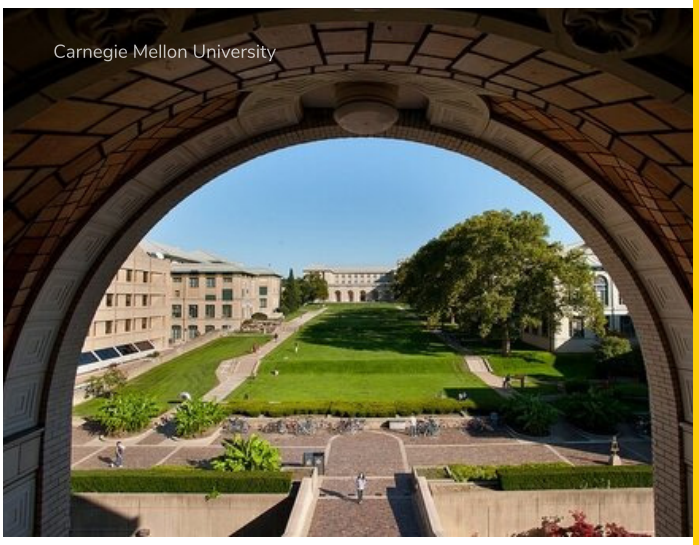
STEM-in-Society programs that integrate project-based learning opportunities for STEM students who are otherwise used to more independent pedagogical approaches benefit students by more accurately preparing them for professional work.

Recruiting Engineering Majors to a STEM-in-Society Degree Program

Despite the demonstrated benefits of the additional major, recruiting undergraduate engineering students is an ongoing challenge for EPP. Fewer than 10 percent of engineering majors pursue the EPP additional major, and most EPP undergraduates come from only two departments (Civil and Environmental Engineering and Mechanical Engineering). Faculty would like to increase enrollment and have more even representation of all nine departments in the College of Engineering.

> *We are definitely 90% engineering students. It's not even across the programs either. A third of our students are probably civil and environmental engineering primary majors, and half of the civil and environmental students are also EPP. So there's a huge mix there. Another third of our students are probably mechanical engineering primary, but that's only a 10th of their program.* **—FACULTY**

One challenge is that recruiters and student advisors within STEM-in-Society programs like EPP must justify the value of their less technical, non-STEM program; more typical engineering degree programs don't have this additional burden. To market EPP to prospective students and/or their parents, faculty and staff highlight the skills students will gain (e.g., project management, teamwork, and responsible engineering) and how this will improve their employability in the short-term and give them skills they will use them throughout their careers, in some instances more so than their technical skills.


Carnegie Mellon University

> *If you're borrowing money, you wanna know that your child's gonna have a job and be able to pay back loans or make that investment worthwhile. [...] How do you convince more students that [...] the skills that we're developing are what you're gonna use 98% of your day? [...] Any alum that I could bring in that's 5–10 years out, to talk to a general audience of engineering first year students, I would ask point blank, what are the three biggest skills that you need in your job today, and what skills should these students be developing? And it's gonna be communication, teamwork, and critical thinking. And that does not mean you take another coding class.* **— FACULTY**

This highlights how marketing STEM-in-Society degrees is challenging due to the lack of understanding of what these programs offer and longstanding field-based norms that position technical skills as superior to interdisciplinary programs.

STEM-in-Society Graduate Education Rooted in Technical Training

EPP's PhD program integrates social and policy perspectives, rather than focusing strictly on the technical aspects of engineering education. From the program's conception, EPP wanted to offer a fundamentally different technology policy curriculum and learning space unique to Carnegie Mellon. Students study a wide range of topics including risk analysis, climate and environment, energy systems, information and communication technology, and technology innovation policy. In addition to taking core policy analysis courses, they are required to complete multiple courses within four broader fields of study: quantitative methods, economics, social science electives, and technical electives. Fifty years after its founding, the doctoral program still has few peers to compare itself to.[57]

To ensure prospective students are prepared for the program's technical demands, each applicant meets with a faculty member during the admissions process who stresses the technical side of the curriculum and what will be expected of them. This vetting process ensures that each student, including those without prior engineering training, understands the program's technical content and related requirements. While an engineering degree is not a prerequisite for admission, the majority of EPP graduate students enter the PhD program with a technical background in engineering or the physical sciences.

Multiple students and alumni noted that they discovered EPP through an internet search of "engineering and policy" or a similar search phrase. These students wanted a program based within a college of engineering so they could maintain or advance their technical expertise. This highlights a potential demand for more STEM-in-Society programs for individuals who want to maintain, or build, their technical expertise while simultaneously gaining and applying additional disciplinary skill sets.

> *I wanted a broader training than just an engineering program would provide. And I didn't want to go a social science route. I still wanted the really technical details that you would get from something like an engineering program. So it provided the perfect blending of technical stuff, numerical methods, analytical methods, but also a broader perspective on policymaking and perception and risk and all these other aspects that you would lose in an engineering program.* **—PHD ALUM**

EPP supports PhD students' intellectual and professional development through extensive coursework requirements, rigorous and applied qualifying exams, and access to learning opportunities that extend beyond EPP and Carnegie Mellon. Students also benefit from a large graduate student body that creates a supportive learning environment.

Cohort-Centered Learning Experience

Interviewees described the PhD program as a friendly, supportive, and intellectually stimulating environment that includes a collaborative culture of peer-to-peer learning. Students value how the program's large size and intensive coursework requirements create an environment where they can discuss shared research interests, learn in a

supportive setting, and develop positive graduate school relationships.

> *One of the things that was really valuable about EPP was sheer size. The three or four years that I was there, there were 100 PhD students all going through three or four of the same courses. [...] That size really does matter, because you might have people who are working on lots of different specific problems, but for a large program, there's a better chance that you'll have clusters of people who find community. And this matters a lot for things like student recruitment.* **—PHD ALUM**

> *All the PhD students have many social events, like talking about their research, talking about things that we found interesting when we were doing our research so that we can help each other or support each other.* **—CURRENT STUDENT**

> *I've heard from other people I know who've done PhDs that PhD programs can sometimes feel competitive at other universities, and it feels like students are pitted against one another and like you're racing to get out publications...and it's like a rat race, and that's definitely not the culture at all at EPP. It's very collaborative; it's very supportive. Everyone's always cheering each other on. I didn't expect to have such good interpersonal relationships that I developed from the program.* **—PHD ALUM**

In these ways, larger STEM-in-Society programs facilitate peer-to-peer and shared learning. They also have the benefit of an alumni base that can be leveraged to help new students learn and network in their early careers.

Instilling A Flexible but Unified Approach to Problem Solving

One of the ways EPP fosters shared learning is by using the doctoral qualifying exams process to prepare students to solve real-world technical problems with social context and a high degree of uncertainty. Qualifying exams consist of a research paper, a public defense of the paper, and a take-home problem. Each year, faculty design a new take home problem that asks PhD students—each student receives the same scenario as their peers—to "solve" a real-world, interdisciplinary challenge with a written response. Their solution must balance the technical aspects of the issue with social considerations. Students are asked to serve the role of analyst and prepare a response in one week. The result of this process is that EPP PhD students gain a unified philosophy and approach to problem-solving that they can use in their careers.

> *There is a recognition that a lot of analysis in the social sciences is, it involves having to deal with uncertainty and more than other people EPP graduates are, I think, able to navigate between two extremes. One where you say, well actually, I've done the math and this is the answer, and not acknowledging that there's uncertainty. And on the other hand saying that actually everything is extremely uncertain and we can't say anything quantitative. So there's a middle path between those two things, which EPP folks tend to be more comfortable navigating.* **—PHD ALUM**

Initially, the doctoral qualifying exams primarily assessed students' mastery of core course concepts, but EPP wanted to ensure that its

PhD graduates would gain the ability to tackle messy technology policy problems and conduct interdisciplinary research. However, some students struggled with the new exams' format; they were not prepared for the intensive and open-ended problem. To address this and scaffold student learning, faculty designed a preparatory "Workshop in Applied Policy Analysis" course that gives students the opportunity to practice problem-solving scenarios that are similar to what they will receive for their qualifying exam.

> *I think the department is good at responding to feedback from students and considering what that looks like. We have a student advisory board and the department's pretty good at listening. We met with the department chair every month and he was good at listening to our feedback and incorporating it.* **—CURRENT STUDENT**

EPP's reflective and adaptable approach to its curriculum design demonstrates how STEM-in-Society programs can use evaluation and student feedback to inform program changes that help better prepare their students for professional work and, in particular, to conduct interdisciplinary research.

Baked-in Flexibility: "CMU is built to be interdisciplinary."

Carnegie Mellon's vocational roots and subsequent emphasis on applied research and training fosters a university culture that supports EPP's own interdisciplinary culture and curricular flexibility. For example, EPP PhD students must complete coursework in quantitative methods, technical electives, and the social sciences, but the program allows each student to tailor these courses to their interests and research goals. Quantitative methods courses may include probability and statistics, optimization, machine learning, or game theory, and technical electives include engineering, science, applied mathematics, and statistics. Social science electives may include quantitative research methods or political science and social processes in addition to required coursework in political science, regulation, or law, and students are expected to "develop a healthy sense of cultural relativism, a notion of the way in which values and social organizations shape our thinking, and an understanding of the way in which these factors have changed and can change with time."[58] Students have the flexibility to fulfill elective requirements outside of EPP or the College of Engineering.

> *I think the best part is definitely I think representative of CMU as a whole, where it's a very interdisciplinary school and program. I'm literally allowed to take, within reason, any class that I want. And I think that's extremely beautiful because even for someone like me who has niche expertise and technical skills and backgrounds, I'm still able to find so many classes that I want to take.* **—CURRENT STUDENT**

Students and alumni also highlighted the ability to network beyond CMU as another program benefit. Faculty routinely help students build relationships with off-campus researchers and faculty in order to both build their networks and also to find the appropriate and best expertise to serve on dissertation committees.

> *The range of stuff that we work on in EPP is very broad, and we don't wanna be limited by*

> *the expertise we can find just across Carnegie Mellon. It's been a source of enormous strength that we can reach out and recruit help all over the place.* —**FACULTY**

Interdisciplinarity and the ability to pursue a combination of interests are often a draw for prospective STEM-in-Society students. EPP makes it easy for PhD students to take courses outside of EPP so they can explore interests that extend beyond EPP faculty expertise.

Professional Development and Career Outcomes

Career Benefits for STEM-in-Society-trained Engineers

Obtaining the EPP additional major has both short- and long-term career benefits for undergraduate engineering students. EPP students outcompete their peers when they enter the job market because employers value their public policy knowledge, social research and report writing skills, and their collaborative teamwork experience.

> *If you come to CMU to recruit, you know that you're getting students that are very well technically trained. So how do you choose between ECE [Environmental and civil engineering] major A and B that have essentially taken the same classes, essentially have the same GPA, essentially have the same extracurriculars. And so my students will say, well, I had EPP and [...] I've taken these other classes, I work interdisciplinary, I've done reports. It's like, wait, you're an ECE major and you can write a report? Sold. So I do hear from students that it really differentiates them from a recruiting standpoint, that this engineering and public policy degree is what they talked about in their interview.* —**FACULTY**

In addition to being more competitive on the job market, EPP graduates' additional experience allows them to shift more quickly into a management role or into an engineering-adjacent field like technology policy advising.

> *There's certainly a lot of them that are going off and getting those traditional jobs, but I think that they move out of that space perhaps quicker than somebody who has not done our program. They see that, as a graduate of this program, I do want to move out into more of a managerial project manager. I can do the coordination piece earlier than say somebody else who is just learning the ropes in business. Or their supervisors recognize this person 'gets it' and pushes them into that space earlier as well.* —**FACULTY**

Their EPP training also opens students' eyes to alternate career paths that they otherwise wouldn't have been familiar with. They might consider working in public policy instead of their original plan to pursue research and development and/or industry roles.

> *Having the EPP curriculum has made me more open to working in a policy-related field rather than just working at a civil and environmental engineering consulting firm. Our undergrad advisor does a really great job of exposing us to alumni and connecting us in some of our classes. And it's been really interesting to hear how EPP has incorporated into all of their jobs where maybe they're working at their consulting firm, but they're doing more policy-related things. So it definitely has made me not wanna stick to just looking at technical engineering stuff.* **—CURRENT STUDENT**

> *I've definitely entertained the idea of just straight up going into government and working in this tech policy space. I don't know if I will, but I think it's really interesting because EPP has this macro look on things that I could see how I could apply my technical skills to better society. Versus if I hadn't done it, I probably would have just gone straight into industry and R&D without even thinking about it.* **—CURRENT STUDENT**

These findings highlight how STEM-in-Society training benefits engineers and other STEM majors by helping them access professional opportunities they otherwise might have discovered much later in their careers.

Preparing PhD Students for the Job Market

EPP PhD alumni work in a variety of academic, private, and public sector positions that bridge policy and research.

> *About a third of our, like 30%, 35% of our PhD students go and get academic jobs. And then the other two thirds, it's overall range from consulting to national labs, to other kinds of industry government positions, of course, they go work with EPA or Department of Energy. So it's a pretty broad mix.* **—FACULTY**

Those who pursue academic roles, however, struggle to market themselves due to the interdisciplinary nature of their degree and acknowledge that they don't necessarily fit in another college of engineering or were not perceived as having enough direct policy training to be competitive when applying for a public policy position. This is partially due to field-based norms and tenure systems that value specific academic journals or specific methodological or research contributions. EPP faculty acknowledged these challenges, but students want more support navigating the academic job market.

> *I think it does tend to be harder for people that have these interdisciplinary degrees to become faculty. You have to really be aware that that's what you wanna do and make sure that you're proving yourself through publications or taking the right courses along the way so that you can actually get a faculty spot in a public policy or in economics or in engineering department, if that's what you wanna do.* **—CURRENT STUDENT**

> *EPP is actually a difficult place to be because there are not a lot of places that know what to do with you. I have applied to Schools of Public Policy where the chair of the hiring committee kind of calls you and says, look, personally I would, I think you would be great here, but this is School of Public Policy, and we have economists and political scientists who publish in such and such journals. And while everyone would recognize that you've*

done valuable work, we really wouldn't know how to get you tenured here, so, sorry. And you can have similar conversations with engineering departments who, unless you're inventing some method or doing some bench work, don't necessarily think that what you're doing is engineering, even though you are applying engineering in ways that it is not applied usually. So it gets really tricky, to find a place that is comfortable with you and that you are comfortable with. **— PHD ALUM**

This demonstrates how STEM-in-Society program graduates can struggle with forming their professional identities due to the unique nature of their education. It also highlights the challenges of fitting into disciplinary molds that academic institutions uphold despite the wide recognition of the benefits of interdisciplinary training.

Emerging Opportunities and Challenges

Expanding Program Impact Through Policy Engagement and Public Outreach

EPP PhD students and alumni would like to see the department develop more comprehensive and structured policy engagement and public outreach and integrate applied student learning opportunities into these activities. Interviewees agreed that a STEM-in-Society program like EPP is well-positioned, especially with its large and growing alumni network in Washington, D.C., to connect more with policymakers, organizations, and general publics. Student interviewees would like to see EPP play a larger role in federal policy engagement and technology policy conversations in the public sphere. Examples given included creating and intentionally sharing usable policy briefs, policy-oriented white papers, and best practices guides with policy practitioners.

Programs like EPP definitely should reach out more and should have a very active, public face in terms of these kinds of conversations on tech, because that's the more practical conversations. We don't live in labs or experiments. We live with real world people with real world scenarios. So I would love to see a more public facing EPP, or more inclusive EPP, in a sense that in terms of public engagement. That would be much better for us. **—PHD ALUM**

I think the focus is still very much on academic papers, which I understand in academic institutions is important, but I would love to see a better avenue for counting or for valuing more policy-oriented white papers, tech notes, practice guides, and things that are geared towards practitioners. **—CURRENT STUDENT**

Building clearer connections between EPP and policy makers is important to students who want to understand the policy implications of their work,

build relationships with policy professionals, and explore related career options. One way EPP could address this need is by continuing to engage with, and expanding contact with, its growing alumni network.

> *I think one thing that I like to have is more connection with alumni to see where they are working, what kind of jobs they have and how their research has helped them in their current jobs. So that when I'm working on my own research in planning for my future steps, I can consider those things.* **—CURRENT STUDENT**

For several years, EPP organized an annual Washington, D.C. trip where students met with alumni working in public policy. More recently, graduate students took over trip planning with financial assistance from the department. Due to the success and popularity of this opportunity, the department will dedicate staff time to planning future DC networking and professional development trips.

> *I've really been always just interested in that intersection between policy making decisions and decisions in the private sector and by individuals and how those two inform each other. [...] I wish that we still had the office in D.C. because I think it just made it easier for faculty to connect their research with policymakers.* **—CURRENT STUDENT**

> *You get to meet with all kinds of different alumni across, there's people who work directly for the government, there's people in consulting, there's people in the National Academies. So, we try to get a broad range of alumni contact that way. I think that was just incredibly valuable, getting to see the range of things that folks were doing with a degree in EPP. And most of the alumni were from the PhD program, but there were a few who had done the undergrad double major in EPP that we reached out to as alumni as well. So it wasn't just the PhD folks who we met with.* **—CURRENT STUDENT**

In general, STEM-in-Society students need more opportunities to explore the real-world implications and policy applications of their research and expertise. The easiest way for students to access these opportunities is if they are built-in to their curricular requirements or co-curricular opportunities.

Maintaining Faculty Expertise in STEM-in-Society Programs

In recent years, natural faculty turnover has affected the courses and research mentorship opportunities that are available to EP graduate students. Interviewees were concerned that, without faculty expertise in behavioral science and decision making, for example, students will have less exposure to the range of social science tools and applications.

> *We've just had the same set of professors for a long time and we've lost some faculty without hiring to replace them, but that is starting to turn around. And particularly in the space of decision making and behavior and decision science, we really have a gap for that right now.* **—CURRENT STUDENT**

Both students and alumni noted this shift in the availability of specific faculty fields of expertise. This is especially concerning because students with engineering backgrounds often already

have some biases towards specific fields. Moving forward, interviewees would like to see EPP reestablish its faculty expertise, and at the time of our interviews, the department was conducting faculty searches to fill vacant positions and supplement its faculty expertise.

> *EPP has sort of lost some of its interdisciplinarity. [...] And so there is a risk that EPP falls into the trap that a lot of policy-oriented departments fall into, which is that they start to act as if the only social science that matters is economics. Because engineers feel comfortable with economics which has the most kind of positivist view of the social sciences. And there's a risk that EPP falls into that trap.* **—PHD ALUM**

Building a well-rounded faculty body to support a graduate-level STEM-in-Society program is particularly challenging because students are entering graduate school with a variety of prior work experience and research interests. Unlike traditional departments where the faculty share a PhD discipline and therefore are likely to offer somewhat consistent training over time, multi-disciplinary STEM-in-Society programs are much more vulnerable to the impacts of faculty turnover.

Summary

The Department of Engineering and Public Policy is unique among STEM-in-Society programs, namely for its positioning within a college of engineering, emphasis on providing supplementary training to undergraduate engineering majors, and unique approach to doctoral education. It is situated in a broader university culture that prioritizes applied learning and broader, real-world applications of engineering. EPP has benefitted from consistent leadership, with only two directors over its history. This combination of university history and culture, a clear education vision, and consistent leadership empowered EPP to develop from a degree program to a fully fledged department that could create tenure track faculty positions and host multiple degree programs.

EPP's PhD program has a large alumni network of researchers, technology policy experts, and faculty who share a similar perspective and approach to problem solving. Key to this is graduates' approach to navigating the technical analysis of science and engineering problems while acknowledging the social and policy contexts that challenge purely technical solutions by introducing uncertainties. EPP's undergraduate additional major provides contextual knowledge and skills that supplement students' primary degrees without adding a burdensome number of new course requirements. The program's capstone projects and streamlined requirements attract students, and students with this additional major stand out from their non-EPP engineering peers when they enter the job market. EPP also has the potential to expand its undergraduate and master's degree programs in the future. The EPP additional major currently reaches a small proportion of undergraduate engineering majors, and the similar additional major

in Science, Technology and Public Policy, offered to non-engineering majors, also has the potential to recruit and serve a greater number of students.

Alumni and current students were overwhelmingly satisfied with their education and career applications of their EPP degrees. However, disciplinary norms continue to make it challenging for STEM-in-Society graduates, including EPP PhDs, to fully realize their academic identities and obtain tenure-track faculty roles. Interviewees recommended EPP strengthen its emphasis on practical skills for graduates going into academic faculty positions and alumni interested in policy-related careers. Some students, depending on their specific research applications, have the opportunity to present to related industry professionals and inform technology and industry decision makers, but these opportunities are unique to each student's particular circumstances and faculty advisor's projects.

EPP students and alumni would also like to see a greater emphasis on policymaking and public engagement in the form of publishing more public-facing communications pieces such as technology white papers and policy briefs. Students and alumni believe that EPP is well-positioned to participate more directly, or perhaps in a more unified manner, in policy advising, analysis, and outreach. We found limited examples of connections between EPP and Carnegie Mellon's School of Public Policy and Management, possibly because of the natural isolation that comes with being an engineering department embedded in an engineering college. This suggests that EPP could potentially create more direct opportunities for students to take advantage of public policy offerings across different parts of the Carnegie Mellon campus.

CASE STUDY

Department of Science, Technology, and Society at Virginia Tech

HIGHLIGHTS

- Virginia Tech's Science and Technology Studies doctoral program serves both mid-career professionals and traditional academic-track students by offering hybrid and part-time learning options at two campus locations in addition to traditional full-time graduate study.
- Growing interest and research investment in STEM-in-Society topics presents both challenges and opportunities for the Virginia Tech Department of Science, Technology, and Society (Virginia Tech STS).
- Establishing a new undergraduate STS major requires navigating a complex and multi-year process for creating a new degree program in the state of Virginia.[59]
- University-level initiatives benefit Virginia Tech STS faculty and students by facilitating interdisciplinary research partnerships with colleagues from across Virginia Tech and providing seed funding for multi-disciplinary projects.

History and Institutional Context

The Virginia Tech Department of Science, Technology, and Society (Virginia Tech STS) illustrates how a STEM-in-Society program can serve both academic-track students and mid-career professionals by providing multiple and flexible graduate program options. It also highlights how a long-standing science, technology, and society program is affected by a growing interest in STEM-in-Society and the proliferation of related projects. Like the majority of STEM-in-Society programs, Virginia Tech STS sits within a large, research-focused

higher education institution. This, in addition to the university's engineering emphasis, creates opportunities for STS ideas to reach STEM students. In fact, many department faculty and students have engineering backgrounds and now focus on engineering cultures and the relationships between engineering, technology, and society. The increased availability of STEM research funding and growing interest in STEM-in-Society, combined with declining financial support for the humanities, presents incentives for Virginia Tech STS faculty and students to collaborate across campus and create relevant coursework opportunities for STEM students.

> *It started out as a reading group among a bunch of people across campus. A lot of scientists, some folks from the social sciences and humanities. And then there was this Dean, in what was then College of Arts and Sciences, who really supported the idea of an STS program. And so it got support under that particular dean, who then created us as a program and managed all of the MOUs and everything that that involved. And this is similar I think to many STS programs that came out of a kind of radical ferment, right. A lot of scientists trying to kind of figure out what they were doing and how what they did mattered in the world and those kinds of questions. And engaged with a bunch of folks from the humanities and social sciences who had some thoughts on those matters as well.*
> **—FACULTY**

Virginia Tech STS evolved from a reading group made up of a multi-disciplinary group of faculty interested in the social context and consequences of scientific research. A supportive dean helped create undergraduate STS minor, master's, and doctoral degrees in the 1980s which were initially housed within a Center for Interdisciplinary Studies. At that time, multiple departments (Sociology, Political Science, Philosophy, and History) working under a cooperative agreement oversaw the STS degree programs. The department was eventually formed in concurrence with the creation of a new College of Liberal Arts.[60]

Program Size and Audience

Virginia Tech STS focuses both on undergraduate minors and graduate degrees. Table 4 lists the current undergraduate and graduate certificate and degree programs offered by the department, the year each was founded, and approximate annual enrollment for each program. The STS undergraduate minor, MS, and PhD options are the oldest programs and were founded in the 1980s.

The Medicine and Society minor reaches more students than the department's other undergraduate programs, with nearly 60 enrolled students in the 2023-2024 school year. Founded in 2005, this minor gives students a highly flexible option for pursuing interests in topics including, but not limited to, the history of biology, health policy, or gender and science. Pre-health majors (the Virginia Tech equivalent of pre-med) or students pursuing biological sciences degrees are the primary audience for this minor.

Virginia Tech STS also plays a crucial role in helping STEM students, at both the undergraduate and graduate levels, understand the context and

TABLE 4. Education programs offered by the Department of Science, Technology, and Society during the 2023-2024 school year

AUDIENCE	TITLE	DEGREE	FORMAT	YEAR ESTABLISHED	2023-24 ENROLLMENT
Undergraduate	Science, Technology, and Society	Minor	in-person	1983	6
Undergraduate	Humanities, Science, and Environment	Minor	in-person	2006	1
Undergraduate	Medicine and Society	Minor	in-person	2005	59
Graduate	Politics and Policy Studies of Science and Technology	Certificate	in-person	2005*	0
Graduate	Nuclear Science, Technology, and Policy	Certificate	in-person	2018	1
Graduate	Science and Technology Studies	Certificate	in-person	2005*	2
Graduate	Bioethics	Certificate	in-person	2023	1
Graduate	Science and Technology Studies	MS	In-person; hybrid	1986	14
Graduate	Science and Technology Studies	PhD	In-person; hybrid	1986	56

*Approximate year program was established.

Source: Department of Science, Technology, and Society, Virginia Tech

consequences of their work. Its faculty open several of their courses to non-STS graduate students, and some have designed or co-designed STS courses for STEM majors, which enables students to bring STS insights into their technical work. For example, one upper-level undergraduate "Algorithms and Society" course is cross-listed with the Department of Computer Science and focuses on ethics and justice in computer algorithms.

Like other STEM-in-Society programs, Virginia Tech STS also offers courses that fulfill general elective requirements for undergraduates.[61] This includes categories such as "critical thinking in the humanities," "ethical reasoning," and "intercultural and global awareness." This is a good way for undergraduates to discover the field of STS.

> *All of our courses are in some way connected around those ideas and those values. And sometimes, if you're really clever, a course will be connected to a couple of them. And so on the one hand, students find STS just that way because they have these electives they need and these satisfy those general electives.* — **FACULTY**

Building long-standing relationships with advisors in other departments and colleges helps promote these options. Over the years, Virginia Tech STS has built connections with the College of Engineering, and the College's advisors now promote its "Engineering Cultures" course to undergraduate engineering students.[62] However, these courses must be carefully designed to provide training to STS students while being accessible to others.

> *It's tricky because an Intro to Science and Technology Studies, for example, you want it to be open enough so that if somebody is coming from, say, computer science, that they could come into that class. But at the same time, you want it so that you're introducing your own new students in the ways of the field, and that can be tricky. But some of the elective graduate seminars do a really good job at this, and some of our courses are explicitly aimed at external audiences. For example, we have a History of Science graduate seminar that is aimed at science teachers. These are master's students and it helps them satisfy requirements for their programs. Another one is a bioethics course that has proved beneficial to a bunch of different departments in the biological sciences and health sciences.* **—FACULTY**

We focused our analysis on the Science and Technology Studies PhD.

Doctoral Training for Dual Audiences

The STS PhD program serves two audiences by offering the same degree in two locations and offering a part-time enrollment option. Students interested in pursuing academic careers typically enroll and attend full-time on Virginia Tech's main campus in Blacksburg, whereas working professionals attend part-time through the National Capital Region (NCR) campus in the Washington, D.C. area.

> *We are one program across two campuses. The main Virginia Tech campus is in Blacksburg, which is in far southwest Virginia. But we also have a campus up in Northern Virginia in the DC metropolitan area and we have had full-time faculty up there since 2000. [...] It's a complicated mix and complicated relationship, but as much as we can all of our program policies are the same. All of our class expectations are the same.* **—FACULTY**

Both types of students bring a diverse set of academic backgrounds including history, cybersecurity, engineering, and business administration, but their professional backgrounds and career stage is typically what sets the two groups apart. Blacksburg students often have humanities or social sciences backgrounds and are more likely to have taken undergraduate courses in STS. In contrast, NCR students are often in their mid- to late careers and more likely to have master's degrees in business administration, engineering, informational technology, or another non-STS field. Many NCR students have worked for a federal agency or a military branch for years before pursuing a PhD.

> *In Blacksburg, it's a much more traditional graduate student population, one to four years out of undergrad generally. [They] sometimes have a little bit of work experience or maybe have gone to do a master's degree in another university first before coming to us, although we accept students without master's degrees.*

> *[...] Our DC students are mid- to late career professionals. Generally they take our program part time because they're maintaining a full time job. A lot of them are associated in one way or another with the kind of DC ecosystem. So they're either in government offices, government agencies, working directly with government agencies and some are very high level administrator types. Some are more in the bureaucracy or the beltway bandit ecosystem. Others are consultants and contractors that sit around the government and in the DC area. And we have a bunch of folks from the military as well.* **—FACULTY**

Virginia Tech STS maintains the same expectations and program policies for both part-time and full-time students and leverages program flexibility to attract and retain PhD students with different motivations and post-graduate career goals. The part-time option appeals to students who need to balance coursework and research while working full-time or managing other life obligations. PhD students on both campuses can choose from nighttime, hybrid, and online course options that are more accessible for working professionals, and they are encouraged to explore a range of potential research interests and dissertation foci. Graduate students can also transfer prior course credits to partially cover degree requirements. PhD students and alumni appreciated the program's flexibility and cited this as one of the reasons they chose to attend Virginia Tech.

> *Instead of only being limited to the STS department, I can take courses all throughout Virginia Tech and all throughout [George Mason University] Mason and even take courses kind of either virtually or through directed reading projects with folks in Blacksburg. So it's just like a tremendous opportunity to really focus on what you want and have that fit with your career goals. And I know of few places that offer that kind of flexibility.* **—CURRENT STUDENT**

> *Flexibility to allow for a better work life balance was important. [...] I had a full time-job. I have a family with young kids, so it was a lot of juggling. It required a lot of time management and all that. My program here and people that I met made it very clear that they will work with me, that they will help me deal with everything in my life. They will allow me the flexibility that I need. There was no requirement to select to go full time or part time. I had a choice to do it as fast or as slow as I wanted.* **—PHD ALUM**

Students are also given a high degree of flexibility to determine their research focus, and faculty advisors help their students identify and pursue appropriate learning opportunities.

> *The advisors, if you express interest in an opportunity or you express that I want to look at something in this direction, I'm not sure where to go, if you express that to someone, they will help you find opportunities to develop those skills. And that's a huge part of why I feel like I enjoy the program so much.* **— CURRENT STUDENT**

> *I really appreciate Virginia Tech's flexibility. They are super accommodating when it comes to what you want to do and what you want to focus on. Especially for an interdisciplinary degree, and there's no escaping that part, they do a really good job of not dictating to you what you need to do with your career and, oh, this is what an STS person looks like. So that's really helpful.* **—CURRENT STUDENT**

Faculty members' willingness to help PhD students create a degree plan that fits their individual needs demonstrates how STEM-in-Society programs more broadly can provide flexible options to attract students with varying interests, professional backgrounds, and career goals.

Integrating Applied and Academic Experiences in the Classroom

Those with practical experience, including those with STEM and policy backgrounds, enhance STEM-in-Society programs by bringing unique perspectives and real-world context into classroom discussions. NCR PhD students bring their experiences working in the policy sector, technology consulting, or the military into their courses. This enables them to ground what they are learning in real-world contexts while applying more holistic perspectives and analytical tools to their professional work.

> *What was really special to me was the fact that I had been working for several years. Coming back to school and that type of program, I had a very different perspective than I would have if I had gone straight through. I'm very glad that I did it from a professional perspective. I'm glad that I took that gap from the academics, because there's a lot of ground truthing that I felt like I could do, having been in the federal government for almost a decade when I went back. And then it was also just, I think, a lot more meaningful. Everything made a lot more sense to me, and I could place it in a context. It wasn't abstract. [...] It really enriched my professional practice to then augment it with this whole new suite of academic knowledge and really deepen a look at the issues, the STS issues.* **—PHD ALUM**

> *Anything I got from the program, I will say, was a supplement or a boost to where I was before I started the program, in terms of giving me perspectives to think about. Certainly I got well-versed in research methods and things that I wouldn't necessarily have picked up if I hadn't done the degree. It introduces you to all kinds of theories and ways of looking at how science, technology, and society work, and how different actors work vis-a-vis science and technology.* **—PHD ALUM**

While students who have stayed in the academy bring knowledge of the scholarly literature and the history of scholarly debates, those with STEM or policy backgrounds bring their real-world experiences navigating the ethical and political challenges posed by science and technology. Virginia Tech STS also hires adjunct instructors,

"Faculty members' willingness to help PhD students create a degree plan that fits their individual needs demonstrates how STEM-in-Society programs more broadly can provide flexible options to attract students with varying interests, professional backgrounds, and career goals."

including their own PhDs, who bring examples from their work experiences into the classroom to promote student engagement and discussion. This promotes more pragmatic and policy-oriented discussions in a way that a typical STS program might not be able to pursue.

> *We have a very strong policy orientation, partly because of our closeness with DC and that half of our students are in the DC area and are in policy institutions. So even when we're teaching non-policy STS, there's always a kind of policy bent to it because our students are in that world and they bring that perspective into the classroom very often.* —**FACULTY**

> *I really appreciate that Virginia Tech has the DC campus, which deliberately courts people who are more senior in their careers. I generally think it elevates the discussion. I generally think they're more mature and better to work with. They've just been out there like, and you know what? I was a dumb punk kid at one point too, and we all still have some of that in us, but there's just like, it's just a lot easier to work with people who have like, had to be working and like had their livelihood depend on it for the past, decade or two as opposed to like someone who just entered a PhD program.* —**CURRENT STUDENT**

For the most part, our interviewees reported the varied student body as an asset to the program. However, there were sometimes clashes of viewpoints and learning needs. Students with a lot of professional experience sometimes react apprehensively to STS theory and related classroom discussions because they find them too abstract.

> *My [NCR] students, they're just not so intrigued with a whole bunch of theory and getting to the depths of the full breadth of intersectionality. Not that they don't listen, and not that everybody isn't polite, but sometimes they're like, oh man this is really what I had to sit and listen to for, you know. So they have a different worldview, if you will, and a different... One of my students called it his BS meter.* —**FACULTY**

Students also had mixed reactions to hybrid learning environments with some feeling that it optimized mutual learning and facilitated discussions. Others struggled with the format and believed it exacerbated professional differences between the two student groups.

> *I struggled a bit with the couple of courses that I took that were co-taught between the two campuses. Most notably the Intro to STS core course that I took in my first year. It was really tough. It was very clear that there were two distinct groups of people that were not only separated by distance but separated by other things as well, and it was really difficult to kind of bridge that gap. It worked much better when I was able to meet them in-person than when you were encountering them online in the context of a course for the first time. [...] I would've welcomed more opportunities to get together because I enjoyed meeting those folks and learning from them.* —**PHD ALUM**

These challenges demonstrate the difficulties other STEM-in-Society programs may face when trying to serve multiple audiences with one degree program.

Professional Development and Career Outcomes

Serving PhD Students with Varying Motivations and Career Goals

Motivations for pursuing an STS PhD vary widely based on individuals' backgrounds and professional ambitions. Blacksburg campus students tend to pursue academic careers, whereas NCR students generally want to pivot or advance in their non-academic careers. The latter typically need supplementary knowledge and skills to help them understand the sociopolitical and ethical dimensions of the technical problems they are trying to solve.

> *The students in Blacksburg, most go into academia or either a tenure track or non-traditional academic kind of appointment. […] Folks from the DC campus rarely go into academia. We've had a couple, super successful folks go off into academia, but that's not the norm. Generally, they are going to use the PhD as a way to either shift jobs or move up through their career. […] Usually it's some problem that they're trying to work out or an interest that's sparked by their experiences in the administrative world. And then they come back to school as a way to think through and build their career in a different direction to really be able to add that policy dimension or to add an ethics dimension or to just better understand the place of whatever the technologies are that they're working on in the broader social context.* **—FACULTY**

This highlights that one potential avenue for training responsible researchers is reaching them mid-career. STEM-in-Society programs designed for working professionals can help them become more responsible researchers by introducing core STS concepts. Individuals with more work experience can draw from, and reflect on, their experience as part of their learning journey.

Providing career guidance to these two groups is challenging for a number of reasons. For one, academic positions for STS PhDs are in short supply. The competitive academic job market is not unique to STEM-in-Society PhDs, but there are few free-standing STEM-in-Society departments. To secure academic positions, STS PhDs need to identify positions where their training in history, engineering cultures, and philosophy of science and technology would be an asset, such as STEM departments looking to supplement their technical expertise with social scientists. This requires reflecting on their academic identity and understanding how to communicate how their knowledge and skill sets would be an asset to non-STS departments.

> *We do have to set ourselves up for the job market in a way where you're like, okay, well you do this work, you might be good for an anthropology department or sociology department and catering maybe the way that you talk about your research in a way that would make you applicable to those different departments.* **—CURRENT PHD STUDENT**

Recruiting PhD students when the academic job

market is so poor is also an ethical dilemma for Virginia Tech STS. For these reasons, interviewees agree that the department needs to help students understand non-academic career options and better prepare PhD students for both academic and non-academic careers.

> *We try to be as clear as we can with students coming in that, one, academia isn't the only be all and end all, and two, that an STS degree offers possibilities outside of the academy.* —**FACULTY**

> *We have been wrestling a lot recently with trying to develop and really think about non-academic trajectories and careers for our Blacksburg students, just because the job market in academia is hard, it's tight. We have an ethical quandary in a way of what does it mean to train students toward a doctorate when the academic job market is so tight. And one way that we're trying to think our way out of that kind of ethical problem is to really start to think in a proactive way about what kinds of non-academic jobs are available and appropriate for students in STS with PhDs. We're starting to map that out a little bit better and to offer that more explicitly to our students as they're looking at our program, thinking about our program coming in, in the early years, et cetera. We're at an early stage of doing that right now, but that's our goal.* —**FACULTY**

One way students cope with this is by utilizing a pragmatic job search approach that stresses flexibility and a willingness to be open to a wider range of both academic and professional careers. They understand that this is necessary to secure a position and are open to pivoting as needed in order to gain employment.

> *If academia would not work out for me, I was prepared to progress my career, I was in the government and potentially pivot to the Department of Health and Human Services or the CDC.* —**PHD ALUM**

Providing non-academic career support is challenging because Virginia Tech STS does not have dedicated career services staff, and most faculty lack the time and experience outside academia to help students build varied professional networks.

> *I think for the most part they try to meet us where we're at in terms of what we wanna do. Although, I do feel like if you're a student in Blacksburg and you aren't wanting to do academics, some of the professors aren't as equipped to help with that. And so they do reach out to a lot of alumni from the Northern Virginia campus to help out with that.* —**CURRENT STUDENT**

To partially fill this void, faculty connect current students with alumni who are willing to share career advice during visiting talks and job opportunities via a department listserv. However, student-alumni networking is largely ad hoc, and both students and alumni would like to see these connections formalized and expanded. Increasing alumni engagement would require the department to track alumni and connect them with current students interested in understanding their career options through networking.

Engineering programs seeking STEM-in-Society expertise are one area Virginia Tech STS alumni have had success gaining academic positions. With their expertise in engineering cultures and engineering studies, multiple PhD graduates have secured postdoctoral or tenure track faculty

positions within engineering education programs. Newer funding opportunities such as the National Science Foundation's (NSF) "Revolutionizing Engineering Departments" grants are designed to extend prior engineering education research and improve engineering students' learning experiences by emphasizing "organizational and cultural change within the departments."[63] However, this requires a complete rethinking of what it means to provide engineering education, and STS-trained scholars are well-positioned to contribute to these efforts.

Unfortunately, some have observed the co-opting of STS-like ideas without acknowledgement of the existing base of STS concepts or recognizing that their own expertise is limited. Interviewees mentioned several dangers to these projects that are primarily led by engineers who lack social science and STS training. This is a recurring theme across case studies, where STEM-in-Society program alumni are often isolated in professional settings or required to do extra labor to explain the legitimacy of their field and expertise.

> *I don't think they have a real sense that what they're doing might fly in engineering education circles, but it absolutely would not fly in STS circles and that they might wanna think about that. […] I do think that a lot of the "STS work" that's going on in associated fields like engineering education in some places has a lot more to do with making engineers feel better about themselves than it does actually make meaningful change. So if there's one takeaway, stop throwing money at engineers to do things that they haven't thought about, haven't really considered other perspectives on and aren't equipped to do.* **—PHD ALUM**

> *I do feel like there is kind of an idea that if you've got the technical side of things, you can pick up all the other stuff along the way without really thinking about it deeply or engaging with it on its own terms.* **—PHD ALUM**

Graduates of STS programs who are hired to help with these projects are often the sole STS-trained individual working within an engineering culture that has entirely different values, systems, and norms. Engineering programs or other STEM fields can use cluster hires to avoid positioning individuals in this way, but typically these departments are hiring post-doctoral positions for temporary projects that received funding for some social aspects of engineering; engineering curriculum revision projects; or diversity, equity, and inclusion in engineering initiatives. Another STS alum who works at a federal agency driven by technical concerns recognized this and wished more of their agency colleagues had STEM-in-Society training.

> *Things like human values, people don't really think about that. The things that underlie why it is we do what we do, or who could be impacted by what we do, who might have good ideas to bring into what we do, those things don't come up. They just don't. And like I said, there's a handful of us who think in these terms, and we have tried in various ways, shapes, and forms to infuse some of that into the agency. It's really hard. And yes, I wish more people had that kind of training because I think it just would allow for a more informed… It would just allow for our decisions to be more informed and not just driven by "just get it done to meet these objectives," but thinking along the impacts and opportunities along the way, the societal impacts and opportunities.* **—PHD ALUM**

These examples highlight the challenges STEM-in-Society experts face once they enter academic or professional environments where they are often the sole STS-trained (or other STEM-in-Society field) individual working in places that are culturally hostile to new ideas or critical perspectives. STEM-in-Society professionals need continued professional support and similarly trained colleagues, so they are not isolated and pushed out of these environments where their expertise is much needed.

Emerging Opportunities and Challenges

Leveraging Virginia Tech's New DC Innovation Campus

In 2025, Virginia Tech is replacing the NCR with a new Innovation Campus that promises to provide students with "hands-on experience working with industry and government to tackle real problems, accelerate your impact, and supercharge your career from day one."[64] The new campus should help Virginia Tech STS continue its track record of reaching graduate students with backgrounds in STEM, the military, and public policy. Virginia Tech STS faculty based at the NCR are now housed in the same building as Virginia Tech's DC-based policy and public affairs programs, which will increase their connections to and partnership opportunities with DC-area policymakers. In addition, faculty expect to increase enrollment by providing elective and other courses for students enrolled in new Master of Engineering degrees in Computer Engineering and Computer Science and Applications. In this way, faculty hope that the expansion of Virginia Tech's DC-area master's programs, and specifically those that emphasize emergent technologies, will help maintain STS graduate courses that are otherwise vulnerable to being cut due to low enrollment. There may also be opportunities to provide ethics training for students who will enroll in the Innovation Campuses' growing engineering programs.

> *The best structural program would be lots of masters, a few PhD students. And then you could have your courses and your PhD students. It would all be great. That's not the market here in the DC Area. [...] With the change in the innovation campus, there'll be all these other courses, service courses that'll be part of our teaching load up here that'll help us stay afloat with our small graduate classes.*
> **—FACULTY**

> *Virginia Tech's putting a lot of money into graduate programs in DC. The big amount of money is going into graduate master's programs in computer engineering and computer science. [...] Right now, they're just focused on getting I think 750—the number of graduates they wanna put out is incredible. And I'm wondering if there's a role for our program offering the ethics classes for these engineering students because ABET, which is the engineering accreditation board, they have a certain level of these and the number*

> *of these credits that you need to have to be an engineering student.* **—FACULTY**

In the past, recruiting NCR-based PhD students was challenging due to the increasing number of STEM-in-Society programs in the Washington, D.C. metropolitan area. Further, without student-recruitment staff, faculty bear the responsibility of networking with companies, nonprofits, and agencies who may have staff interested in pursuing higher education. When the NCR option started in 2000, Virginia Tech STS had only one local full-time faculty member. Now there are three tenure track faculty at the NCR campus, and the department hires adjunct faculty to teach NCR campus courses on an as-needed basis. As the Innovation Campus grows, Virginia Tech STS may be able to access new resources and relationships that will, in turn, serve STS PhD students by connecting them with other students and faculty across both STEM and policy fields.

Adapting to the Globalization of STEM-in-Society Issues

STEM-in-Society programs must adapt to meet student interests, address emerging science and technology issues, and adjust to natural changes in leadership and faculty expertise that occur over time. Virginia Tech STS is currently focusing on a revision of its graduate program curriculum and diversifying its faculty body and expertise. Interviewees noted that STS as a field has shifted to emphasize equity, justice, and international science and technology issues. In response to both these changes and shifts in student interests, the department recently initiated its first systematic curriculum revision in 20 years. They have also hired new faculty whose research emphasizes international science and technology issues.

> *Our faculty has grown quite a bit over the last decade, by about 50%, and that has given us some opportunity to rethink some of our teaching traditional categories, ways that we can sort of imagine and conceptualize what STS is and where the field sits. We've brought in a lot more international scholars as a response to changes and broadening of the field. STS [...] has really globalized and it requires a lot of rethinking and proactive kind of engagement. We've been really trying to pay attention to that.* **—FACULTY**

> *We've made a lot of changes over the years, just not in any kind of systematic way. It's always been, it's all been very piecemeal. So we've gone back and done a really systematic review of what it is that we're doing, why we're doing it, what we're teaching, what we require of students.* **—FACULTY**

STEM-in-Society programs are somewhat unique from other academic programs in that they need more frequent reviews and curriculum updates in order to stay current as STEM-in-Society issues change.

Growing Undergraduate Programs in the Future

To increase its student impact and campus presence, Virginia Tech STS plans to launch a new undergraduate major in STS or a related field such as science, technology, and public affairs. STEM-in-Society programs are often incentivized to offer undergraduate programs, especially majors, because they provide stability and legitimacy in a

university environment that favors undergraduate enrollment metrics. Having an undergraduate major would also help the department meet undergraduate impact metrics driven by university-wide expectations of how many undergraduate students each department should be reaching. This points out the complicated position STEM-in-Society programs can be in when, despite the success of undergraduate minor programs and teaching service, they do not meet university-wide expectations for undergraduate enrollment.

> *It's not that we need an undergraduate major, it just feels like it would complete the package a little bit. It would help to stabilize our teaching, planning, and all of that. It would help to give the department another focus as well, and the university metrics come and go and they change over time. And sometimes undergraduate teaching becomes a really important metric, and when that happens, we always get a little nervous, and so it would help to ease that set of anxieties as well over time.* **—FACULTY**

> *We struggle a little bit with undergraduate teaching and classes and filling classes because we don't have a major. We are moving in that direction and we're in conversations right now to get a major in the next few years that is something more along the lines of science, technology and public affairs or public policy or something of that sort.* **—FACULTY**

A new undergraduate major would provide an alternative degree option for students who want more in-depth STEM-in-Society training than the current STS minor offers. Similar to the EPP additional major at Carnegie Mellon, some undergraduates may pursue a second degree to supplement their STEM training and increase their employability or advancement potential. Additionally, reaching students earlier better prepares them to be more responsible researchers or professionals throughout their careers.

> *At the undergraduate level we're often teaching a lot of STEM students and we're really their introduction to different ways of thinking and trying to get them to think critically or holistically or in different kinds of ways. […] I think that the first thing we offer is a sense of perspective and context for the life that they're living in the world that's happening around them, where it came from. What are its major tensions and controversies and what are the consequences of the choices that have been made? What are the consequences of science and technology? What possible futures are there? And I think that that's the kind of thing that they're rarely offered in their STEM courses. […] From a more skill based level, it's about analysis a lot. How to read texts, how to look at scientific and technological and medical texts in the context of, as arguments and as ideas connected in a political and economic landscape.* **—FACULTY**

However, creating a new major is a challenging bureaucratic process. Virginia Tech STS must gain approval from multiple bodies across the university and the state as well as the Southern Association of Colleges and Schools Commission on Colleges. This process is particularly difficult because STS is a lesser known field of study which often deals with issues of social equity and justice and is therefore particularly vulnerable to politically-motivated critiques or suspicion. Further, Virginia does not allow new degrees to duplicate existing degrees anywhere in the state.

> *We'd like to be able to get a major, but we've been stymied at the state level for a number of years. State politics are very complicated and it's been a difficult set of conversations. STS to some individuals is not recognizable as a thing, as a meaningful category, and it can make it very difficult to get the degree through bureaucracies [...] It's complicated because in the state of Virginia, in order to start a new degree program, you have to get it approved not only by your college and by the university and by your Board of Visitors, but by a state governing body in Virginia. And it made it up to that level. And then they decided that it wasn't a good idea. And this was all kind of right before the techlash we've experienced over the past handful of years. So I think if it had happened like a year later, it would've been a different scene.* **—FACULTY**

STEM-in-Society programs like Virginia Tech STS would benefit from external validation from trusted institutions and individuals who can vouch for the field and its importance. STEM-in-Society programs that have struggled similarly with expanding their programs could also share lessons learned to facilitate mutual learning across STEM-in-Society programs and develop successful strategies to translate the importance of these programs for students and broader publics.

Navigating the Explosion of STEM-in-Society Across Campus

As at other universities, Virginia Tech has seen a proliferation of initiatives focused on the intersection between science, technology, and society. Examples include the Technology for Humanity Initiative, which is designed to assert Virginia Tech as a human-centered university that emphasizes "the societal impact of technological innovation through human-centered approaches."[65] While Virginia Tech STS faculty appreciate that STEM departments and researchers have begun to recognize the importance of these issues, they also believe that they have an important role to play in contributing to, and even leading, these efforts and breaking down disciplinary campus silos.

> *In some ways STS, as an intellectual practice and community, has sort of taken over the university. Everybody now is concerned with sort of social context and social values and ethics... And you see this in both rhetorical and material ways. [...] So over in the science department, I see them hiring people who are bridging, they're very technical, they're science people... but they have some kind of STS training or they've spent time in a policy arena doing serious policy work. And so you're getting these individuals over in the sciences who are actually doing sometimes, not always, fairly sophisticated social-technical interface work. And they're really interested in that and they build networks and they bring complex grants together. And then in the humanities and the social sciences as well, I look around our college and everybody in the college has like one STS person or another STS person in their department. So it used to be that there were these sort of STSy people and they all glommed together because there were so few of them and they needed a kind of intellectual home. And now every department does STS.* **—FACULTY**

However, new university initiatives can make it difficult for long-standing STEM-in-Society programs to maintain their unique value

proposition on campus and to students. For example, Virginia Tech's Technology for Humanity Initiative funds the development of new courses related to human-centered technological design. While interviewees appreciate the growing interest in these topics, there is a concern that faculty without STS training, or any STEM-in-Society education, could overextend themselves by designing courses that don't acknowledge foundational STS concepts. This is complicated by the view that STS is a discipline with blurred boundaries.

> *A challenge for us is to kind of stay relevant and to stay meaningful in this context. What is it that the department is adding to the university when all these other people all over the university are doing what we do (but also maybe not as well, right)? We all have our critiques, but nevertheless, there's all these really interesting, very sophisticated people out there doing STSy connected work. And how do we as a department manage that? [...] People are always trying to teach STS courses in these other departments 'cause that's what they do, right? And do we stand in their way and say, no, all the STS courses have to be here in our department? What does that mean? What does that look like? Why would we do that? So there's this whole kind of complication of the success of the STS project for a department like ours.* **—FACULTY**

Much like the experiences of UC Santa Cruz interviewees, this is further complicated by the power differential between STEM fields and STS, which is primarily composed of humanists and social scientists, especially at an engineering-focused university like Virginia Tech. STS faculty must be careful about participating in collaborative projects with STEM faculty that treat STS experts as an afterthought to an already-developed project proposal.

> *I don't necessarily think that STS being valuable to other fields is a bad thing. I do think that STS being tokenized for other fields, to be able to check a box and do whatever they were gonna do anyway, that is really worrying to me.* **—PHD ALUM**

> *We're working through this right now, we're struggling with this a little bit— what it looks like to not just be the STS person on a grant, but to actually lead these larger collaborative institutional grants and where we would want to head with that, what makes sense for our faculty, what makes sense for our department that's where I think our biggest struggles are over the next few years.* **—FACULTY**

Several case studies demonstrate how STEM-in-Society experts with previous STEM training or detailed STEM knowledge can build respectful relationships with STEM faculty and students who have a bias that their fields are superior to humanities and STS. This is true for Virginia Tech STS faculty and alumni who are able leverage their prior STEM training and knowledge as a way to build relationships with STEM faculty or colleagues.

> *One of the things I would say that helped me, is I was originally trained as an undergraduate in engineering and I started doing the history of science as an undergrad. And so I've always had this like, code switching thing. And I would say that for not all of our faculty, but for some of our faculty, it's the same thing.* **—FACULTY**

Overall, the department is trying to react

to growing interest in the social and ethical dimensions of STEM with a collegial mindset that emphasizes network-building and a collaborative approach. It maintains a list of faculty across campus whose work relates to STS and is growing its affiliate faculty to build a cross-campus network of individuals interested in STS and "STS-like" topics. Some faculty are shifting from a typical independent research model to projects that involve STEM faculty and students. This requires building relationships and navigating more complicated projects that involve multiple faculty from across the university who represent different fields of study and different scholarly norms and expected research outcomes.

> *Historically, [...] we've been in a very humanities individual investigator model. So each faculty member has their own projects, their own thing, if they're writing grants, they're writing individual grants for themselves and maybe a student or two who they're going to employ for a couple of years, that kind of thing. But as we look at the landscape, I think it's becoming clearer to us that at least some small number of our grants and some amount of our energy probably needs to be focused on collaborative work. Really starting to think about large collaborative projects, large, even inter-institutional or multi-institutional, or at least intercollegiate right across the colleges at the university kinds of projects. And I think that our Department has not been really great about doing that in the past.* **—FACULTY**

Campus-level initiatives such as non-departmental research centers or institutes can provide a neutral convening space for STEM-in-Society program faculty and students to find collaborators and support for new research or education initiatives.

Some Virginia Tech STS faculty are already involved in new campus research centers that focus on the relationships between emerging technologies and society. They try to integrate graduate students into these projects by building in financial support for graduate student research or administrative assistants. For example, Virginia Tech STS is involved in the Institute for Creativity, Arts and Technology (ICAT), which convenes faculty and students across disciplines and provides funding to pursue innovative and mutually beneficial research and education. This includes collaborative projects and new courses, physical space and labs for researchers, and technical multimedia expertise. Spaces like the ICAT provide a convening space for STS faculty and students to find potential collaborators.

> *The way that this program was set up, it required that you had an engineering education research person and a "social scientist" on the team. And so I worked through that with the electrical and computer engineering department on trying to alter their culture and curriculum in ways that align with this notion of STEM and... STEM and society was part of it.* **—FACULTY**

Virginia Tech STS faculty will continue to foster and build cross-campus relationships across Virginia Tech's campuses and leverage collaborations to secure multi-year funding opportunities. This is one way STEM-in-Society faculty can assert their expertise amidst a proliferation of interest in science and technology ethics and policy across college campuses. It also helps them fund their research and provide students with funding in the form of research assistantships.

Summary

Virginia Tech STS demonstrates how STEM-in-Society PhD programs can serve students with varied professional experiences and career goals. Virginia Tech STS serves students with a diversity of previous experience, prior knowledge, and future career goals by offering a part-time option and hybrid or online courses. After originally establishing its PhD program for students seeking academic positions in the humanities and social sciences, the department later expanded to serve Washington, D.C., area professionals seeking to pivot or advance their careers. In this way, Virginia Tech STS may be a good model for STEM-in-Society programs seeking to serve the growing number of STEM professionals eager to participate in more responsible research and innovation. While this dual-audience approach has been successful, providing professional development to both audiences can be challenging due to decreased availability of academic positions and a lack of career advising capacity. Leveraging alumni networks to help students understand the broader applicability of their PhDs is one way this program is attempting to help students understand non-academic professional options.

This case also highlights the challenges and opportunities long-standing STEM-in-Society programs face with growing public and academic attention on the social and ethical consequences of emerging science and technology. In the coming decade, Virginia Tech STS will likely shift its research and fundraising approach from an STS-centric and independent research model to a more collaborative and multi-unit or multi-institution framework. This will help it assert its expertise across campus while helping students develop more cross-disciplinary skills. It will also, however, require STEM-in-Society faculty, students, and graduates to challenge the norms and power dynamics in STEM fields, which is both emotionally and intellectually taxing.

CASE STUDY

Science, Technology, and Public Policy Program at the University of Michigan

HIGHLIGHTS

- The Science, Technology, and Public Policy Program (STPP) at the University of Michigan (U-M) attracts graduate students from both STEM and non-STEM fields who envision a wide range of careers from academic research to policy work.
- STPP's graduate certificate shapes graduate students' short and long-term career goals by preparing them to be more responsible researchers and innovators and helping them identify non-academic professional options.
- Extracurricular programs train STPP students to critically assess new technologies, provide policy briefs including recommendations to policymakers, and serve as consultants to community organizations grappling with current science and technology justice issues.
- STPP alumni use and value their interdisciplinary skills, including critical thinking, stakeholder engagement, and policy writing.
- Creating a single staff position provided the catalyst for STPP to grow its funding capacity, hire additional staff, and establish new research and community engagement programs.

History and Institutional Context

The Science, Technology, and Public Policy Program (STPP) at the University of Michigan demonstrates how STEM-in-Society programs can combine formal education programs, research assistantships, and community engagement initiatives to train students to practice responsible

research and technology development and engage in public policy to advance the public interest. STPP is a research center within the Gerald R. Ford School of Public Policy (Ford School) at U-M. Founded in 2006, it initially housed a graduate certificate and postdoctoral fellowship program, designed and overseen by a faculty director with the help of a part-time student assistant. STPP has since grown to include undergraduate programming, applied research projects, faculty affiliates, and six full-time, grant-funded staff who support the center's expanding work. STPP's mission is to "advance the public interest, and specifically social equity and justice, in the development and governance of science and technology through education, research, and community and policy engagement."[66]

STPP's long-standing certificate offers graduate students interested in the social, ethical, and policy dimensions of emerging science and technology the structure to pursue these interests while obtaining a credential that will help them pursue related careers. The STPP certificate also provides students from across U-M access to Ford School courses, a specialized writing center, and networking opportunities with high-level visiting speakers and alumni.

Approximately 62% of certificate students come from STEM fields (there are no prerequisites), and 19% from the Ford School itself.[67] In recent years, STPP has also increased support for undergraduates through courses, career support, and developing student organizations. In addition, STPP hires a limited number of student research assistants through the Technology Assessment Project (TAP) and Community Partnerships Initiative (CPI). TAP researchers gain experience analyzing contemporary science and technology issues with a critical historical lens, writing for policy audiences, and providing recommendations to policymakers and community organizations. Students hired by CPI conduct research for local governments and community organizations grappling with a science and technology policy or responsible research and innovation issue.

The STPP certificate impacts students' professional identities and careers. Many STPP certificate alums who previously planned STEM research careers shift to policy roles, while those who stay in STEM are more adept at understanding the needs and concerns of citizens and translating them into responsible research and technology. STPP alumni hold an array of professional roles, including in academia, public service, consulting, and the non-profit sector, where they routinely find themselves in translational positions that require understanding both the technical and sociopolitical aspects of science and technology issues. In the long-term, they value and prioritize STEM-in-Society skills more in their own work and seek to hire scientists, engineers, and policy professionals with similar skill sets.

Since the research center's inception, ensuring capacity and funding for both its certificate program and new initiatives have been its primary challenge. Organizational culture challenges and leadership changes within the Ford School have also shifted how much institutional support STPP has received over time. Initially the faculty director had course releases and a small budget to hire a part-time student research assistant. By 2018, a supportive dean agreed to fund a full-time program manager but reduced course releases for the faculty director. The full time staff member increased student recruitment and enrollment and renewed program activities including a lecture series that had lapsed during a change in

STPP leadership. Together, the faculty director and program manager pursued external funding opportunities, which led to multiple university and foundation grants and an alumni donation, which enabled more programming and staff hires. The program manager eventually became STPP's managing director.

In the next five to ten years, STPP plans to expand its educational programs further to serve new audiences, including a formalized undergraduate credential (e.g., a science and technology policy minor), a state legislative fellowship program, and additional training options for post-doctoral and mid-career professionals. It also plans to expand its research portfolio, through additional government and foundation grants. These initiatives will depend on the ability to maintain diverse funding streams and navigate relationships with Ford School leadership and other U-M faculty and units. Maintaining funding to sustain STPP's growing array of programs, and planning new initiatives carefully, will be the center's biggest challenge.

Program Size and Audience

In the 2023-2024 school year, the STPP graduate certificate had just over 100 current students at different stages of completion. 40% of them were master's and 60% were doctoral students, and students' primary degrees included medical and biology fields (e.g., neuroscience, microbiology and immunology, and genetics), engineering, public policy, and environmental studies (e.g., environment and sustainability).[68] The certificate introduces students to foundational science and technology studies concepts and policy skills while encouraging them to pursue their own science and technology interests. STPP graduate certificate students learn how to anticipate and analyze the social and ethical dimensions of science and technology, conduct policy analysis, influence politics, and communicate to public and policy audiences in both oral and written form.

STPP's approach is grounded in the field of STS. Faculty and staff emphasized how they use it to help students understand the history and social contexts that determine how science, technology, and related public policies are designed and implemented. First and foremost is the concept that science and society are deeply related, and scientific knowledge is political.

> *They get a really sophisticated understanding, I think, of the ways in which science and technology are forms of political and social power and the implications of that for publics.*
> **—FACULTY**

With this foundation, students learn to think more deeply about the development and governance of science and technology and gain policy-relevant skills including critical thinking (e.g., What are the connections between research and social benefit?), memo writing, and how to assess policy environments. STEM-in-Society programs like STPP supplement STEM education by providing STEM students with skill sets and rigorous training opportunities unavailable in their primary programs, despite the growing attention to responsible research and innovation at universities.

Students must take two core courses and two

electives, which can be taken in any order. The core course that often serves as the entryway to the program, "Introduction to Science and Technology Policy Analysis," introduces students to theories and methodologies related to the interactions between science, technology, public policy, and society with an emphasis on "the roles of government agencies, expert advisory committees, private industry, the courts, and the public."[69] This course was designed for students from a range of disciplinary backgrounds and degree programs and does not require any specific scientific or technical background. Readings, lectures, and discussions draw from a range of disciplines, including political science, economics, sociology, and history, as well as STS. Students also learn how to use a range of policy analysis tools to understand research funding allocation methods and innovation, including assessing emerging controversies related to science and technology.

This blend of foundational concepts and skills-based learning also characterizes the other required core course. "Political Environment of Policymaking" furthers student understanding of how politics shapes various aspects of policymaking. Students can choose among course sections with different foci including the domestic United States context, cross-national, international, and environmental policy. Through this course, students also develop their policy analysis, writing, and oral communication skills. STEM students in particular gain a marketable skill set quite different from what they get in their primary degree programs which emphasize technical writing and academic publishing.

> *They are learning the practical skills of policy writing and policy analysis and policy communication. Writing for policy is really different from any other kind of writing, and the Ford School is really excellent at teaching it. And so they get pretty intensive training in how to write for policy, and they get access to the Ford School's specialized writing instructors. And it's one of the things that makes our students competitive in the marketplace. Especially our STEM graduate students, they're not learning how to write anywhere else, or the kind of writing that they're learning how to do is very passive voice, it's very technical, it's in many ways the opposite of policy writing.* **—STAFF**

Many STPP students enter the certificate program with preconceived ideas of how policymaking functions, including the assumption that scientific research operates outside of society or politics. One of the fundamental lessons STPP teaches is that science is a social institution that is influenced by politics. Through class discussions and assignments, they gain a more intricate understanding of the policy process including how policies are designed, implemented, and assessed and who gets to participate in these processes. STPP certificate students also learn how to use new social frameworks and policy analysis tools to understand science and technology issues and related policy decisions.

> *The one class I think that sticks out to me most [...] was about biotechnology policy. We picked a topic and for the entire semester, we increasingly analyzed the situation around that topic. Having the opportunity to sort of pick your frog that you're going to partially dissect over and over and understand more and more the rigid challenges and cultural implications of all these different things, that process was my mental rewiring out of technical scientific analysis to policy and sociological analysis.*

> *By the end of the course, I had found that it fundamentally restructured my approach to problem-solving. I didn't lose my technical problem-solving mental approach. I gained a second one and did that cross training into different ways of thinking. I still use that every single day.* **—CERTIFICATE ALUM**

To ensure students gain worthwhile knowledge and skills, STPP conducts alumni exit surveys and modifies certificate curriculum accordingly. One example is adapting STPP lectures to better serve students' interest in more practitioner type roles (versus social science scholar paths).

> *Many of our students are not interested in following an STS academic career path. They're interested in becoming some kind of policy practitioner. We've shifted our lecture series to be more oriented towards practitioners or if academics, academics who are very tightly tied into community activities or other practical aspects of policy.* **—STAFF**

STPP also eliminated a required course that students found less useful than their other core requirements which both streamlined certificate requirements and better aligned it with other U-M graduate certificate programs that require four courses. Evaluating and adapting programs in response to emerging science and technology issues and student interests is one way STEM-in-Society programs can stay relevant.

Meeting Diverse Student Needs With Program Flexibility

The elective requirement encourages students to explore topics of interest to them or gain specialized knowledge in a specific science/technology topic. Students can either choose from an extensive pre-approved list of courses or petition for a new course to fulfill this requirement.[70] STEM students often choose electives aligned with their primary degree requirements and research interests or explore Ford School courses that more broadly advance their understanding of public policy and policy analysis. Ford School students benefit from taking non-policy courses and gaining topical knowledge. This flexibility sets STPP apart from other science and technology policy programs, which tend to focus on one specific science or technology topic.

> *I also like that it's very, it's such a broad program, so you could sort of pick and choose areas of interest and those would count towards the certificate program. So there was a rigorous element with the required courses, but also this kind of elective possibility which I really liked.* **—CERTIFICATE ALUM**

Providing students with flexibility to pursue their own interests is an important characteristic of STEM-in-Society programs that target a broad or diverse student audience. U-M attracts high-caliber graduate students from around the world and, in turn, STPP convenes students with a range of academic backgrounds and expertise so they can consider different perspectives when discussing policy issues. One of STPP's strengths is its use of interdisciplinary perspectives to explore science and technology issues, and this attracts students who have been previously isolated in their respective disciplines.

> *We're bringing all of these different disciplinary perspectives together into the classroom, and they have a chance to learn from each other, learn how to communicate*

> *with each other. They start to learn what I think of as one of the core lessons of the program, which is about expertise and who is usually recognized as being an expert versus who actually has expertise. So when we have, for example, a computer scientist who has been trained that their technical expertise is highly specialized and no one else has it, when they start to learn from policy students who are in their classes, social work students who are in their classes, and start to see that there's so many more ways of knowing things and so much more expertise that's relevant to their own work. I think that that's really powerful.* **—STAFF**

Intermixing students from across U-M's campus creates an energizing space for teaching and discussion. By taking Ford School courses, STEM students interact with non-STEM peers who have a completely different worldview and underlying view of science and technology issues. This process is important for helping students understand that their expertise, values, and worldviews as scientists and disciplinary experts are not more important than other perspectives.

> *The multidisciplinary classroom space to me is one of the most exciting and invigorating parts of it. Having students with technical expertise in the same space as policy students, it's really challenging, in my experience, to get those students to learn from each other, 'cause sometimes they... Let's just say sometimes some of the scientists are a bit arrogant and don't recognize the expertise of the policy students, but I think it's a really important cross-disciplinary learning environment.* **—FACULTY**

Building diverse certificate cohorts helps students explore the multifaceted sociopolitical aspects of science and technology issues, but in practice presents challenges. STPP leaders recognize that STEM students can be discouraged when beginning the certificate. For many this is their first introduction to social science, and they often lack an understanding of how science and technology issues are addressed by policymakers or what policy careers look like.

> *I always really salute those students because it's such a set of challenges. They're not used to reading for social science. They're not used to this kind of writing. They're not used to this kind of discussion-based classes. In the last 15 years I've integrated guest lectures into my courses, and we now have these alumni webinars, partially because I think the students have no idea of what a policy career could look like.* **—FACULTY**

STPP promotes a positive learning environment by integrating certificate students in the Ford School more broadly. Having access to a student listserv, faculty, and events helps non-Ford School STPP students feel welcome and more motivated to pursue policy-related careers.

> *That's one thing that I really enjoy with it being folded into the Ford School is that, as an STPP certificate student, you have access to a lot of the resources that's just broadly offered to Ford students. I go to a lot of the policy talks that aren't necessarily part of the STPP program. But as far as the STPP program, I've also gone to a couple of the talks where we've also had the opportunity to get lunch with the speakers. And I've really enjoyed kind of actually getting to speak with people that in many cases are like me and have a background in bench top science and then*

> *transition to something more policy related.* — **CURRENT STUDENT**

> *Just the fact that we get those Sunday night emails from the dean, it makes us feel more a part of the community instead of this additional thing on top of it. I feel like I know just as much of what's going on in Ford, honestly sometimes more than I do in my own department. So I think it's nice that they don't put us in a box of oh, we are just gonna send them updates about the STPP program.* — **CURRENT STUDENT**

This points out how graduate students often feel isolated within their home campus unit, each with its own culture, ways of communicating, and perspectives on interdisciplinary learning. In turn, recruiting certificate participants takes a lot of effort, especially when students are highly dependent on one, or only a few, faculty members for research guidance and professional mentorship. In response, STPP faculty and staff conduct intentional outreach across U-M's campus, often relying on previous cohort data to see which majors are underrepresented in the certificate program and adjusting their recruitment accordingly. In this way, STPP staff use strategic outreach to ensure each STPP cohort represents a range of disciplines and related student expertise.[71] Students discover the certificate in a number of ways, which points to the importance of using multiple channels and techniques to recruit STEM-in-Society students. Prospective and future Ford School students often discover STPP while exploring the school's website, courses, and offerings. The majority, however, learn about the program once they are already on campus, either through current certificate students, program alumni, STPP staff outreach, or their initial graduate school orientation that makes students aware of the U-M's graduate certificate options.

Student Motivations for Pursuing STEM-in-Society Training

Understanding student motivations for pursuing STEM-in-Society training can inform program design by demonstrating the curricular and co-curricular opportunities that students need.

Students have a range of motivations for pursuing the STPP graduate certificate. For some, it is a chance to understand the broader ethical context of their own STEM research. Others simply lacked time to pursue interdisciplinary interests as undergraduates and see the certificate as another chance to do so. Lastly, many students want to keep their professional options open and are seeking an opportunity to pivot from bench research into more policy-focused careers. STPP provides a structured, analytical way to view science and technology issues and, in turn, help students recognize the policy relevance of their own research. Students also want to gain specific skills, including analytical tools for understanding contemporary science and technology issues, communicating science for non-scientific audiences, and graduating with writing samples they can use to demonstrate their skills to potential employers. In particular, students want to be able to communicate more effectively with policymakers as subject matter experts.

> *The classes we're taking, you get the experience of writing in the policy style. Moving forward, especially for someone like me who maybe wants to move away from bench science into the policy world... One,*

it's really good experience and also you walk away with writing samples. And I think that's also valuable for job applications or fellowship applications. **—CURRENT CERTIFICATE STUDENT**

If there's a headline, if there's a major advance or an ethical question about the development or application of technology or science, especially as it relates to law and how societies deal with some of these tricky questions, that's always really interested me. […] I was interested, just reading a description of the STPP program, that there's this framework of analysis of bringing analytical tools and frameworks theory into that. **—CERTIFICATE ALUM**

I worked with the government of India in public policy, specifically implementing policies for about eight years. And one thing I really struggled with was how to draw the line between science and non-science because there's a lot of pseudoscience even perpetrated by the government. So how do you break it down for people, especially policy briefs? I feel like policy briefs are all not accessible and I wanted to get tools to, or learn more about how to break it down for the common public. **—CURRENT STUDENT**

Multiple STPP alumni noted that the certificate allowed them to realize a passion or personal interest in science and technology policy that they did not previously have the dedicated space and structure to explore. These students are often STEM experts themselves but also have a natural curiosity and interest in related social issues.

To me what is super compelling about it is the extent to which it really draws students from the sciences and engineering who are already interested in these questions. But who have never had… They don't have a systematic place to think about them and to learn the tools to connect their research practices to the policy implications of their work. **—FACULTY**

I had always just been kind of a nerd when it came to politics and I didn't know what I wanted to do when I finished my PhD. So I thought seeing the opportunity to kind of combine what I was getting trained in academically with one of my interests, was an interesting opportunity. **—CERTIFICATE ALUM**

I think that around my third year, I was starting to feel kind of like, just like isolated in the lab environment, and then, in just like a day-to-day sort of sense. But then also, it felt like the work that I was doing was really, really, really far away from any kind of human impact. I was really craving that and I'd always kind of had an interest in politics and those sorts of things. **—CERTIFICATE ALUM**

Many STEM graduate students have specialized in a particular field since they were undergraduates and assumed graduate school was the logical next step for them. However, many PhD students realize, after dedicating three or more years to building their technical expertise, that they don't want to be bench scientists or pursue an academic research career. This can be a fraught time for those who realize that they want an alternative pathway but lack experience in or knowledge of other fields.

Around this time last year when I was applying to the STPP program, it was more like existential crisis mode. I just really wanted to figure out something that would make me

> *feel fulfilled. It's been not only relieving in a broad sense, I feel I found something, a niche, in my field that I really enjoy, but then I feel like there's also the practical sense where it's like being on the listserv talking to professors or we also get access to the advisors at Ford, which was really exciting for me too. So I feel like I actually know about opportunities and have ideas of things that I want to apply to when it gets close to the graduation date, which is nice as opposed to it just being kind of nebulous.* **—CURRENT STUDENT**

> *I was in my second year of graduate school and about to go through my candidacy exams, and I started realizing I was doing something that I didn't have to do. And for me at least, that resulted in a little bit of a personal existential crisis because I had been building this career to be a professor. And I realized all of a sudden after two years of investment in that work that I didn't wanna be a professor anymore. And I didn't have any understanding of what else I could do. I'd already felt like I'd gone so far down this technical training process that I had locked myself into a career I no longer wanted. And that was really, really scary. And I remember just sort of floundering along for about a year. [...] I remember sitting in that first class and the first set of homework was like 800 pages of reading. And I devoured it. I read it all in two days. And I had never in my life had that reaction to a science paper or a chemistry topic or anything like that. And it just clicked instantly and I realized this is what I was supposed to be doing.* **—CERTIFICATE ALUM**

For these students, the STPP certificate is a low-commitment way to build new skill sets and try to find a professional pathway that allows them to still apply their technical expertise in socially relevant ways. Others have been interested in policy but did not previously have a way to pursue science policy as a career.

> *I came into grad school kind of knowing that I was interested in science policy, but I didn't really know what that meant at all in terms of a career. And I felt like there was not a very well defined path to going from the bench to the science policy world. And so I felt like hopefully doing this certificate would either open doors or at least introduce me to more of what that meant as a career path.* **— CERTIFICATE ALUM**

STEM researchers need tangible ways to explore alternative careers or understand how to become more responsible researchers. STEM-in-Society programs, and graduate-level certificate programs in particular, can provide this training and support.

Michigan Photography

Professional Development and Career Outcomes

STPP students pursue an array of professions, including STEM research or positions in government, think tanks, nonprofits, or industry. The certificate prepares STEM students in particular to both conduct more responsible research and pursue policy-related careers. To prepare them for these roles, STPP students are encouraged to attend visiting speaker talks and meet with the speakers, apply for professional development grants to attend policy-related events or training opportunities, and apply for paid research assistantships. These initiatives have a significant impact on students' professional development, demonstrating how STEM-in-Society programs can supplement students' in-class learning by offering co-curricular options.

Policy Research Builds Professional Skills

To supplement coursework and provide professional development for students interested in transitioning to policy-related careers, STPP hires student research assistants through its Technology Assessment Project (TAP) and Community Partnerships Initiative (CPI). Each school year, STPP employs anywhere from 10 to 15 student research assistants who are a mix of undergraduate public policy majors, graduate public policy master's students, and both master's and doctoral students enrolled in the STPP certificate program.

> *We don't even think about experts in a technical issue as being social scientists. And so my goal from the beginning has been to build STPP into a think tank, primarily one that is using STS somehow somewhere to inform important issues in science and technology policy.* **—FACULTY**

Under TAP, STPP faculty, staff, and students study the implications of a contemporary technology issue and offer recommendations for better policies and governance surrounding the technology. TAP researchers leverage the history of technology to understand emerging issues in science and technology. Student research assistants work in small teams to produce a policy brief that focuses on an emerging technology problem. Though each issue is unique, TAP researchers apply an analytical method where they identify other, similar technologies, consider their development and implementation, and use these to anticipate the implications of the focus technology of interest.

> *It's technology that people would say, oh, we've never seen this before. How can you regulate it? But these new technologies have a lot of similarities from other technologies that were used in the past. We use an analogous method to look at some of the older technologies and what were the problems with those? What were the good things with those? How could we have regulated those? And being able to predict what might be some of the issues with this new thing, to me, I think that is the coolest thing that we do.* **—STAFF**

In addition to student professional development, TAP has increased the recognition of STPP's

expertise in the wake of growing concerns about technologies including artificial intelligence. Indeed, STEM-in-Society programs like STPP host expertise that often goes untapped and unnoticed until a contemporary science and technology issue emerges in public policy sectors or pop culture. TAP publications, and the attention they have received from policymakers and media outlets, have increased STPP's visibility on U-M's campus which in turn helps facilitate cross-campus research collaborations.

> *Our research has enabled us to become more visible. When we were just an education program, we didn't have the same kinds of levers we have to put ourselves out there. But now that we're producing this research, we do. We got a lot of attention from our "Facial Recognition in Schools" report. Our large language models report is continuing to circulate. So that's a big part of it.* **—STAFF**

Publishing research in usable formats (e.g., reports, policy briefs, and policy recommendations) also benefits STPP by introducing policymakers, stakeholders, and organizations grappling with science and technology issues to the Center's expertise and resources.

Relatedly, STPP initiated CPI in 2022 with funding from the Ford Foundation that allowed STPP to hire a Partnerships Coordinator. Under CPI, STPP staff and student researchers partner with Michigan-based social justice organizations to address community-driven questions and needs related to science and technology issues. A full-time staff member coordinates this program, serving as a liaison between community organizations and student researchers. They listen to community concerns and, through iterative discussions and research, work together to identify the organization's primary science and technology policy questions. Student research assistants work with STPP staff and the organizations on deliverables that are defined by the organization. Examples include a report, a policy memo or brief, and assisting with dissemination of findings. Student research assistants work in small groups and gain direct experience serving as policy issue consultants by attending project planning meetings, sharing updates, and presenting their findings or other requested products to community partners.

> *We now have a third area of work, our community partnerships work, and that's entirely grant funded. It also interacts with our education programs because we have been able to hire a bunch of students to work to support the partnerships projects.* **—STAFF**

TAP and CPI have enabled STPP to expand its training to include undergraduate students who do not currently have a science and technology policy major, minor, or certificate. STPP also encourages research assistants to use the Ford School's Writing Center to hone analytical writing and policy memo skills. This is especially useful for undergraduates who have not had the opportunity to take policy analysis courses in the Ford School.

> *There are currently no official science and tech policy programs for undergraduates. That's something that we are working on. But one way that we are trying to build towards that is to create these kinds of practical experience opportunities for undergraduates.* **—STAFF**

Understanding the impact of these work opportunities on students' careers is important as a way to both measure current program success but also to inform potential future education

programs. STPP is starting to track employment outcomes for CPI research assistants and at least one CPI research assistant (who graduated with an undergraduate public policy minor) has gone on to gain employment with a CPI client organization. This shows that science and technology policy training is beneficial for improving undergraduate job opportunities and suggests there is room for a formal undergraduate degree program.

Career Outcomes for STPP Graduates

Given the variety of STPP certificate students' backgrounds and goals and the diversity of policy-related careers, STPP faculty and staff do not prescribe specific career outcomes. Instead, they work to support each student and however they want to engage with science and technology policy today and in the future. By dispelling prior assumptions about how policies are made or implemented and developing an appreciation for inclusive stakeholder engagement, STPP improves students' understanding of policy-related careers. Earning a certificate credential also makes STPP alumni more competitive for public service and policy-related roles. However, while some do go on to work on policy advocacy or advising, STPP alumni end up in a range of professional roles. For instance, some remain in academia but apply their STPP training to their teaching or research activities.

> *We don't really have an ideal student, a single kind, in part because of the breadth of training that we offer. But also careers in science policy are so disparate. No two career paths are the same. We know that students are coming to us from lots of different paths, and they're going to follow lots of different paths when they get out.* **—STAFF**

> *They end up in lots of different kinds of roles. We have a very good track record with placing our alumni in the AAAS fellowship and other policy fellowships at the state level. We have a substantial chunk of our alumni who do go into government or in contractor roles. Some go into various kinds of NGOs and advocacy organizations, some go into consulting. And then we do also have a decent number of alumni who stay in academia and go on to have pretty traditional tenure track career paths. But the work that they do is different because of STPP. So they may teach a policy class, or they may do research that's more directly policy oriented. And some go into the private sector. Places like Uber, Duo, and Google.* **—STAFF**

Multiple STPP alumni noted how the STPP certificate either shifted their dissertation research or improved their chances of getting accepted into graduate school or post-graduate fellowships.

> *It totally changed the direction of what I wanted to do for my PhD. I knew I wanted to go into academia, but I think had I not done the certificate, I would be doing something totally different. I think it changed my research methods and how I was thinking about the place that I work in. So even though I'm not doing policy stuff, it changed my research a lot.* **—CERTIFICATE ALUM**

> *Having the policy certificate made me a top candidate for the next grad school that I entered. [...] The fact that I also had this credential in public policy, definitely opened doors here in Washington, D.C. The fact*

> *that I'm a person who can sit at the nexus of technical expertise and political expertise was invaluable to selling myself to various programs and jobs down the line. That second master's degree that I earned is very much along the lines of the STPP program and so there was a lot of overlap in the types of things that I was learning. [...] And it was great to have that in my belt already when I attended that program as well.* —**CERTIFICATE ALUM**

STPP certificate alumni working in different sectors and at different policy levels, ranging from local/regional to the federal-level, apply stakeholder engagement best practices while working with community members on science and technology issues.

> *I took away a lot of great information about how to relate better to specific communities. So to individuals, I learned about IRBs and the ethics of doing research. I think also having a perspective where, when a decision needs to be made, there's a power dynamic involved where there's communities or populations who will feel the consequences of those decisions. And a lot of times, from the president on down to a local city council person or whatever, people don't necessarily have an awareness of the power dynamic there and the possibility of incorporating the voices of people who will be impacted by those decisions more directly. Not just checking a box, but genuinely incorporating their input into the decision itself. And I think that was highlighted and explored pretty deeply in the scientific context in STPP, but I wanted to apply that more in the policymaking and policy implementation world.* —**CERTIFICATE ALUM**

Other alums gained an understanding of consensus building, scientific knowledge, and policy expertise that profoundly impacted their professional work. Learning that STEM expertise, for example, is not the only form of knowledge or most legitimate type of knowledge impacts how they approach their work and careers.

> *A lot of scientists have this perspective of coming in saying, "If only you knew what I knew, you'd believe what I believed. If you had my facts, you'd come to my conclusions." And I think more than anything else, the most important thing that this program does [...] is to break down that line of thinking.* —**CERTIFICATE ALUM**

> *Oftentimes I call back to my training in the Ford School [...] about what does it mean to bring in an expert, who qualifies as an expert, and why is it important to consider different kinds of individuals for these positions and for these committees than just all technical experts and scientists. So absolutely, I continue to find value in the education that I received there.* —**CERTIFICATE ALUM**

This demonstrates the importance of STEM-in-Society training for STEM students who would otherwise continue in their careers without ever realizing that their expertise is not necessarily superior to the social sciences or community-level knowledges.

STPP students also exit the program with a better understanding of science and technology policy career paths. This directly influences their professional experiences and career choices, both in the short and long-term. For example, one certificate alum serving in a federal-level congressional fellowship pointed out how their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certificate training prepared them to serve in this role, in particular noting the written and oral communication training that set them apart from their peers.

> *When I landed in Congress, I was already briefing my senator on week two. I was writing memos, I was doing vote recommendation, I was traveling with him to sites. He was sending me places to represent him. And of my 30 plus fellowship pool, I was literally the only one doing that for a month because it took them that long to understand what they were being asked to do.* —**CERTIFICATE ALUM**

Depending on their capacity to do so, STEM-in-Society programs can provide students with career mentorship and guidance that their primary degree programs do not offer. STEM-in-Society programs like the STPP Certificate help students identify and define their next steps as researchers or help them diversify their career options.

Alumni Prioritize STEM-in-Society Training in Their Hiring Practices

STPP alumni value interdisciplinarity and prioritize candidates with STEM-in-Society training in their own hiring practices. One interviewee described how they favor candidates with STEM-in-Society skills when filling science and technology policy roles within their federal agency. Alumni also reflected that they see an increasing emphasis on STEM-in-Society training and related skills on professional resumes and CVs, in particular among STEM scientists seeking policy-related professional roles.

> *The students who go through these programs, elevate them on their resume and make it a lot more noticeable. And you can tell a difference in the candidates. They are people who have just this clear way of articulating this interface between technical knowledge and how humans interact with each other and the world.* —**CERTIFICATE ALUM**

They also noted, however, that it can be challenging to find applicants with both STEM expertise and STEM-in-Society training who can communicate science and technology issues in a format that is usable for public policy.

> *One of the most important things of working in a policy space is also the thing that we don't teach scientists and it's soft skills. STPP taught me how to write, how to think and analyze, how to remove my own biases from a situation and assess the policy or the proposal or the politics, and how those things are interacting with each other. That's not a qualification, a certificate that you can put on*

> *your resume usually. And it's really really hard to hire people or to select candidates for those skills. [...] I've found myself hiring staff and training staff and applying the lessons and training I gained from STPP like, "This isn't what I asked for. If you need to staple it, it's too long." Things like that. Those are not skills we are taught as scientists.* **—CERTIFICATE ALUM**

Some alumni value their STPP training so much that they refer STEM graduate students interested in policy careers to the STPP certificate program. Ingraining new values in students and early to mid-career professionals is one way STEM-in-Society programs can have a long-term impact on their students and positive ripple effects for the fields more broadly through fostering a network of professionals who value and practice STEM-in-Society values and skills.

Challenges Accessing Career Resources

Providing career services for STPP certificate students is an ongoing challenge. As capacity allows, STPP staff and faculty provide career advice to certificate students and encourage them to network with visiting speakers and STPP alumni. However, they lack the necessary time required to cultivate relationships with potential employers and stay abreast of professional opportunities. Ideally, this is a role that a full-time career services team could fill, but the Ford School's Career Services Office only serves public policy majors. For certificate students with home departments outside of the Ford School, this further limits their ability to understand policy-related career options or how to utilize their STPP training in a professional setting.

> *Ford School students who do the certificate have access to all of the Ford School's career advising, but most of our STPP Graduate Certificate students are not Ford School students and they get their advising from STPP staff. We also plan different kinds of events and things that are targeted as career support.* **—STAFF**

STPP alumni and students noted that their home departments did not have the knowledge or expertise to help them identify policy-related jobs, connect them with relevant professional contacts, or prepare application materials for policy-related positions. As a result, STPP students who want policy-related advising depend on STPP for these services. Limited access to policy-specific career support can be frustrating for students whose home departments cannot provide this guidance.

> *When you're an engineering student they don't know what to tell you to do when you're going into policy. That's not their forte. They're looking at placing you in scientific jobs. There's not a lot of knowledge in the engineering school about how to transition over. And so that's definitely an area where if you have students from a totally different academic background that they're probably going to need more help to apply the things that they've learned with their certificate and find a place for themselves in the world.* **— CERTIFICATE ALUM**

> *When I was a student there and I mentioned this in my exit interview, I'm still kind of annoyed by it all these years later. I went to the sort of counseling job placement folks in the Ford School and they basically told me,*

> *what are you doing here you're an engineer? You're an engineering student, we don't support you. And I said no, I am a [STPP] certificate student also and was told by my advisor to come down and talk to you about what resources might be available through this office and I guess, what you're saying is none. Is that correct? And that was more or less the answer.* **—CERTIFICATE ALUM**

Like Virginia Tech STS, which also lacks dedicated career services staff, STPP engages its alumni network to help current students understand their professional options. STPP staff maintain a detailed alumni database, host annual virtual alumni panels, and moderate a STPP listserv that circulates job and other opportunities. This provides networking opportunities for current certificate students and alumni and provides a space for students to ask questions and learn what STPP alumni or their colleagues look for when hiring.

> *Our collection of alumni is small, but really dedicated. A lot of our alumni, especially from earlier on in the program when this kind of training was even rarer, they really credit STPP with changing the course of their careers, and the result is that they're available to talk to our students. We do alumni webinars. They made themselves available for informational interviews and things like that. They help keep us up to date on what's happening in the field and what kinds of things they're hiring for.* **— STAFF**

One improvement STPP has made is gaining access to "FordCareers," the Ford School's web-based recruiting system that certificate students can use to search and apply for national and international job and internship postings. This resource is an asset to students, and STPP staff had to work to get STPP students' access to the FordCareers system. This demonstrates how STEM-in-Society programs designed to serve a large number of students with a variety of backgrounds can struggle to provide sufficient career services to program participants. Despite incorporating STPP certificate students into the Ford School in many ways, certificate students whose primary academic home is outside of the Ford School cannot fully utilize the Ford School's Career Services Office. Higher education silos, longstanding and nuanced program histories, and related capacity challenges more broadly all play a role in shaping the resources STEM-in-Society staff, and in turn students, can access.

Emerging Opportunities and Challenges

Diversifying Funding Streams to Build Research Center Capacity

STPP is a relatively autonomous entity from the Ford School, resulting in shifts over time in terms of what kind of financial and student services resources it can access. Increasing this division, STPP administers its graduate certificate

separately from all other Ford School degrees. Additionally, and like other STEM-in-Society programs based in research centers or distinct campus units, STPP initially relied on its founding leader to design, oversee, and maintain all aspects of program administration including fundraising, teaching, program design, and research. As a research center, however, STPP lacks the same dedicated, full-time faculty that other campus units have, making it harder to self-sustain in terms of leadership, fundraising, and grant-writing.

> *This is an issue across the University of Michigan where centers are very closely tied to an individual faculty member and they often have a life cycle of about 10 years. [...] They're so closely tied to a faculty member and that causes various kinds of problems.* **—STAFF**

This can manifest in a loss of institutional knowledge and personal investment during periods of leadership change. From 2011-2016, for example, STPP's faculty director position was filled by another faculty member who did not maintain co-curricular or recruitment activities. While required certificate courses were still taught during this period, students did not have access to the lecture series; they received little course or career counseling; and certificate enrollment decreased. At that point STPP had no full-time staff to assist with program activities, and program faculty and staff had to build up certificate program enrollment again in the years that followed.

Recruiting new leadership is challenging for STPP because it is fiscally separate from the Ford School's faculty hiring lines. This puts more pressure on the founding director to stay in their leadership position to avoid the risk of the program lapsing in their absence. Such a model is also unfortunate for the program, which cannot benefit from new energy and ideas that a new leader might bring. STPP is addressing this by pursuing university-wide faculty recruitment efforts that emphasize science and technology policy expertise and building a potential bench of leadership succession. For example, it recently received support from the Ford School to participate in a university-wide faculty cluster that brought a new assistant professor who could potentially serve in a STPP leadership role in the future.

STPP was also fiscally harmed when the university decided not to reward certificate programs for enrolling students. When the STPP graduate certificate program was first established, STPP received funding both from the graduate school for each enrolled student and when a student from another unit took a Ford School course. Today, however, STPP no longer receives funding on a per student basis. This shifted Ford School administrators' view of STPP from considering the certificate an asset to feeling that they were essentially paying their faculty to teach students from other units when they could be teaching Ford School students and drawing in revenue for it.

In response, STPP secured external funding that allowed it to build its staff capacity and allow for strategic planning and new endeavors like TAP and CPI. Meanwhile, Ford School administrators are happier that STPP brings in overhead funding while working on cutting- edge issues. As a result, as noted above, the Dean authorized the hire of and funding for a Program Manager who has since become the Managing Director. Today, the Managing Director is supported primarily by general funds and supplemented with grant funding. Like other research centers, the amount of funding support STPP receives from the School depends on the current Dean's agenda.

> *I think it really matters who the Dean is of the policy school. Which is true for any academic endeavor. The people who are in charge and whether or not they see value and the effort play a really big role.* **—FACULTY**

> *In terms of how we're viewed within the Ford School, I think there's been ups and downs. Our last dean and our current dean were both very supportive of Science and Tech Policy as a field that the Ford School should be in. And also of STPP in particular. Again, it's this shifting understanding that, "Oh, tech policy is something we need to care about and is of value." But also it helps that we're bringing in grants.* **—STAFF**

One benefit of being a research center is that STPP has the flexibility to pursue different funding sources to support its education programs and new initiatives. STPP's newest full-time staff positions are funded primarily by a mix of government and foundation grants and will rely on continuation of these funding sources or securing new grant awards. To maintain its growing staff team, STPP has intentionally focused on multi-year awards and building relationships with foundations that have an interest in science and technology policy and training scientists in ethics and policy.

> *The research centers are much more decentralized in the Ford School. The central administrative offices and programs are a lot more tightly hierarchical and centrally managed, but the research centers are given a lot of freedom. Partly that means we all look different ways, but it means we have a lot of freedom to pursue our own funding. If we can fund something we can do it.* **—STAFF**

STPP demonstrates that adding even one staff position has both immediate and long-term benefits including the ability to further expand staffing capacity over time. However, adding new staff also requires more physical office space and adds to STPP's managing director's staff supervision duties. As STPP successfully brings in new funding sources, including foundation funding, which is unique within the Ford School, it has received more positive attention and support both from Ford School and across U-M more broadly. Moving forward, STPP will need to carefully navigate its fundraising approach by selectively choosing which funding opportunities to pursue in order to both maintain current programs and support new initiatives.

Reaching New Student Audiences

In the coming years and facilitated by a generous alumni donor, STPP intends to develop new undergraduate and professional education programs. It used the funding to hire an education program manager whose work includes designing practical learning experiences for undergraduates and developing formal degree program options.

> *Our first big donor gift was explicitly to increase opportunities for undergraduates. And that's part of what's funded our education program manager position is that gift. And, in addition to practical experiences through TAP and CPI, we're excited about starting to try and create some coursework and think about what kinds of more formalized opportunities would make sense for undergrads.* **—STAFF**

Designing and launching a new degree requires STEM-in-Society programs operating within large, R1 universities to identify similar programs that

will compete for students' attention. While an undergraduate STPP degree option could provide much needed course enrollment dollars, it could also compete with the existing undergraduate science and technology studies minor program offered through the College of Literature, Science, and the Arts. Although U-M's STS program does not currently offer a policy track, the two programs will have to work together to ensure that both programs succeed and do not harm—and perhaps even amplify—one another.

> *In the undergrad STS program students opt into different tracks depending on if they're interested in science, if they're interested in tech, if they're interested in medicine. And I think having a policy track could be valuable as well. I think there are challenges at places like U of M in terms of minors. The number of programs that operate in the STS and STPP space have expanded somewhat. So like at the undergrad level, there's... I don't even know, there's some biology and society major that actually doesn't have any humanistic or social science people teaching in it, but it claims to provide similar kinds of expertise. So, I'll say that it's kind of a saturated market.* **—FACULTY**

STPP is also initiating postdoctoral and mid-career training which stems from its interest in reaching STEM professionals who are increasingly seeking additional training in either responsible research and innovation or science and technology policy. In the past, it has received numerous inquiries from those who want to complete the graduate certificate but are not enrolled graduate students. One approach would be to create an executive education-style professional certificate or "bootcamp" that would introduce STS concepts as they relate to and inform critical science, technology, and policy analysis. STPP has already taken a step in this direction through an open access Coursera course, "Justice and Equity in Technology Policy" which has attracted almost 3,400 learners thus far. [72]

> *We're also really interested in reaching postdocs and mid-career people. We get inquiries pretty regularly from people who find themselves working in some piece of tech or science policy, and that's not their training. They reach out and unfortunately right now the certificate is only open to currently enrolled U of M graduate students.* **—STAFF**

STPP is also creating a state policy legislative program for postgraduate early career scientists and engineers to learn about, develop, and aid state-level policymaking. [73] Staff are also exploring whether STPP courses can be integrated into STEM programs on campus. The Medical School and Engineering Schools at U-M each represent large potential audiences. Disciplinary barriers and the time it takes to foster cross-campus relationships will likely be the primary challenges to implementing any collaborative education programming.

Staying Relevant and Navigating Growing Interest in STEM-in-Society Training

STEM-in-Society programs face a unique challenge in that the main areas of student interest are always changing. As a result, it can be difficult to design curricula that meet all needs. While STPP's core courses can pivot somewhat year-to-year, it cannot provide all students with

examples and case studies that fit their specific interests. The program tends to manage these emerging interests by constantly updating its roster of electives. However, this approach can be frustrating for students who want to learn more about the policy and societal issues associated with their own research specialization.

> *I remember being a little frustrated by how little of the reading material was relevant for specifically what I was doing. It was wide ranging, which was interesting, but I remember reading about CRISPR technologies quite a bit. It was a wide ranging program in the sense that it tried to address a lot of different kinds of sciences and technologies. And not all that was interesting to me. Some of it was, but not all. I remember thinking, I wish there was more about data stuff, big tech stuff, specifically like cloud, data privacy. STPP released this big paper on large language models shortly after I graduated, and I remember being bummed out about that because I would have loved to have talked about that in class.* **—CERTIFICATE ALUM**

STPP alumni had a number of suggestions for how to formalize connections between students' graduate research and the STPP certificate. These included: requiring certificate students doing PhDs to include a Ford School faculty member on their dissertation committee, requiring a policy chapter in PhD students' dissertations, creating an independent research project requirement for certificate participants, and helping students connect with policymakers. These options would provide the dedicated time and structure students need to understand the social, ethical, and policy concerns surrounding their primary research topic. It could also potentially function as a tool for helping students better understand how to work with policymakers and serve as a science or technology experts.

> *There were so many talented students—in our classes and the STPP program—that all probably could have weighed in on their specific domain expertise in a real policy setting. And I think it'd be cool if that program did a better job of connecting specifically active PhD students with legislators who might take advantage of their knowledge. I remember there was one point where Shobita actually went and spoke in front of a house committee. It would have been really cool to hear more about that because she herself is an expert on specific tech or science areas within policy. And I think that was kind of brushed under the rug.* **—CERTIFICATE ALUM**

> *My biggest regret of grad school, professionally at least, is that I didn't put a policy professor on my PhD committee. I wish I had written a policy chapter on the policy ramifications of my research. That's such a simple, easy thing to do, and it would provide deeper, more formalized connections between the policy school and these other programs. [...] Whenever a graduate student, early in their graduate school career, reaches out to me, that is the number one thing I urge them to do, write a chapter in your thesis about the policy ramifications and implications of your thesis.* **—CERTIFICATE ALUM**

Many of these options would not be feasible for master's students who have short degree timelines or PhD students who decide to complete the certificate later in their degree programs. Alumni suggested working around this by replacing one of the certificate elective courses with an independent study that requires each certificate

student to complete an STPP research paper that integrates what they are learning in STPP with their own graduate research. This could be done independently or as part of courses in their home department. While this is not officially an option, at least one past certificate student worked closely with STPP faculty to pursue an independent study that fulfilled their elective requirement and allowed them to pursue their specific interests.

In short, students want more opportunities to tailor their certificate experience to be more directly applicable to their own research and, for some, policy career goals. However, requiring or offering an independent study option would require more faculty and staff advising capacity to support students through this process. This also illustrates the challenges of serving both master's and doctoral students who can have different degree timeframes and levels of interest in STEM-in-Society training.

Summary

The Science, Technology, and Public Policy graduate certificate program introduces students, many of them early career STEM experts, to the sociopolitical aspects of science and technology issues and teaches them critical policy analysis skills that translate to both academic and policy careers. The short- and long-term educational impacts of this nearly 20 year old certificate program range from helping students unpack their preconceived understandings of the policy process to helping STEM researchers realize alternative career options. STPP also demonstrates how a STEM-in-Society research center can integrate its programs in order to serve diverse stakeholders including STEM graduate students, undergraduate research assistants, and community organizations grappling with science and technology challenges. STPP is characterized by a triad of initiatives that fully integrate student learning and professional development.

As a research center within the Ford School, the Science and Technology Policy Program has experienced periods of significant capacity challenges and, more recently, accelerated growth. Initially, STPP needed to build staff capacity from the ground up in order to provide more stability during leadership transitions and changes associated with launching new co-curricular programs. New positive developments also come with related challenges. Most of STPP's permanent staff are funded by soft monies, and maintaining these roles will depend on continuing to secure multi-year funding sources. As STPP has grown, the primary challenge has shifted to maintaining funding and navigating the sustainable growth of STPP's initiatives and staff team.

CASE STUDY

Science and Justice Research Center at the University of California, Santa Cruz

HIGHLIGHTS

- Through its Science and Justice Training Program, the Science and Justice Research Center (SJRC) at the University of California, Santa Cruz (UC Santa Cruz) provides an essential service for PhD students who would otherwise be unable to explore the social and ethical implications of their research.
- Students' ability to participate in the Science and Justice Training Program depends on their research demands, teaching obligations, and field-based cultural norms that influence how their programs value social science training.
- The SJRC convenes UC Santa Cruz affiliates and local community members through a combination of working groups and public events where they can explore and discuss science justice topics.
- In addition to providing UC Santa Cruz with in-demand science ethics and justice expertise, the SJRC dedicates much of its efforts to changing perceptions of the value of STEM-in-Society research and education among UC Santa Cruz's STEM research community.
- SJRC leaders build and leverage cross-campus connections to develop intellectual support for its programs; develop collaborations, including funding partnerships; gain and maintain campus-wide recognition; and hire tenure-track faculty.

History and Institutional Context

The Science and Justice Research Center (SJRC) at the University of California, Santa Cruz (UC Santa Cruz) demonstrates how a justice-centered STEM-in-Society program enables a dedicated space for discussion and exploration of science justice issues while helping to shift perceptions and cultures within the university and academic work. It also demonstrates the challenges and opportunities of building and operating a STEM-in-Society program that engages faculty and students with widely ranging scholarly backgrounds, research interests, and field-specific norms. The Science and Justice Research Center (SJRC) at UC Santa Cruz is unique in its focus on building relationships and mutual understanding among both STEM and non-STEM academics as well as community members and organizations who are all interested in, or affected by, the social justice dimensions of current science and technology issues.

The SJRC was launched In the 2011-2012 academic year to provide a hub for a growing number of science and justice initiatives, including the Science and Justice Working Group and the Science and Justice Training Program (SJTP).[74] The Working Group was organized by and for faculty and graduate students from across campus who wanted to discuss how to integrate social justice and STEM topics, and the SJTP—which awards a Science and Justice Certificate to participating PhD students—was created in 2010 with support from the National Science Foundation. The overarching aim of the SJRC is to create intentional opportunities for graduate fellows, faculty, staff, and community members to convene around common concerns that transcend disciplinary boundaries. It does this by providing dedicated physical space for hosting events, routinely hosting both campus and public events, offering the Science and Justice Certificate credential to PhD students, and pursuing funding opportunities and collaborations focused on science and justice. At present, the SJRC is focused on bringing in new leadership, hiring tenure track STEM faculty for the first time, and creating a new undergraduate certificate program.

UC Santa Cruz is a relatively young public university and land grant institution that joined the University of California system in 1965. At the time, its relatively remote location necessitated the creation of residential colleges; ten residential colleges currently host both education programs and undergraduate student housing. With just under 20,000 enrolled students, UC Santa Cruz is small compared to other public universities, including those in the UC system. Although it emphasizes undergraduate education with roughly 90 percent of the student body being undergraduate students, UC Santa Cruz maintains R1 doctoral university status and offers graduate degrees in over 40 academic fields across the arts and humanities, engineering, physical and biological sciences, and the social sciences. UC Santa Cruz also has a rich history of conducting research and providing education opportunities that emphasize issues of diversity and justice.

> *There's this kind of culture of interdisciplinarity and exploration and also for doing scholarship that has an activist component.* — **CERTIFICATE ALUM**

For example, its History of Consciousness graduate program has been a part of the university since it was established. This program attracted feminist

science scholars and science and technology theorists to the University and contributed to the growth of critical studies of science and technology as a central area of scholarship at UC Santa Cruz.

> *UC Santa Cruz has historically had a research strength in feminist science and technology studies, which is a field that not only looks at women in science and gender and science, but it looks at gender intersectionally. So it thinks about race, class, ability, disability, sexuality, but then also larger questions about science and social justice, science and environmental justice, science and health equity. And there was a real opportunity at Santa Cruz to bring the existing faculty and graduate students working on projects related to feminist science and technology studies together with a broader research community at UC Santa Cruz who are interested in these larger questions about science and justice, but didn't have the tools.* **—CERTIFICATE ALUM**

The combination of UC Santa Cruz's long-standing scholarship in science and technology studies and campus culture of engaging in bigger science and justice questions helped create a conducive setting for creating the SJRC and its use of unique leadership models.

Sustained Leadership Supports Program Longevity

Like EPP and STPP, the SJRC has relied on consistent leadership since its founding, which has helped it sustain its programs despite financial and administrative challenges. In addition, the SJRC's program manager has been with the program for over 10 years, and the knowledge, experience, and relationships they bring helps it to both plan and execute events and build and maintain relationships with target audiences and collaborators.

> *She really helps do this work of outreach. She now knows our worlds here well enough to know who to think to invite. And that's not just the academics, it's the staff people. So, for example, we're doing an event today on AI and recruitment processes. So how AI is being used in those processes of who gets hired and not hired. And we've invited some of our HR people to come. We see it as not just an academic exercise. We see our staff, our community that we live in, and we're engaged in working across sectors and so our audience, if we think a lot about who is the audience and, and how are we creating the "we" of science and justice as we craft our events and who we're inviting and how we're doing that.* **—FACULTY**

"Practicing collaborative decision making defines the SJRC's leadership model and sets it apart from our other cases. It relies on multiple committees to guide its initiatives; a steering committee advises research and community programming; and internal and external advisory committees advise fundraising, visioning and planning, and building partner connections. Graduate students also participated in the design of both the original Science and Justice Working Group and the Science and Justice Training Program."

Practicing collaborative decision making defines the SJRC's leadership model and sets it apart from our other cases. It relies on multiple committees to guide its initiatives; a steering committee advises research and community programming; and internal and external advisory committees advise fundraising, visioning and planning, and building partner connections. Graduate students also participated in the design of both the original Science and Justice Working Group and the Science and Justice Training Program. To flatten the typical power dynamic associated with top-down leadership, the SJRC also initially had two co-directors. After having a single faculty director for several years, the SJRC recently reinstated a co-leadership model to help set up clearer lines of leadership succession. However, despite the intentional steps the SJRC has taken to ensure that the Center and its programs are not reliant on one individual leader, multiple training program alumni commented that the SJRC would not exist without the hard work and dedication of its leaders and the SJRC's faculty director.

> *They've been able to keep their admin person the whole time, and having admin support really matters. That's been one important resource that the institution has supported. […] But I feel it's Jenny being clever and finding all these different ways and talking to people and making stuff happen. And so it's really built on the charisma and skills of one person. Other people have been involved and have done work, but like I said, without the funding, without tenure lines, I mean, I think they should have tenure lines. […] I think the institution missed a great opportunity to grow it.* **—SJTP ALUM**

> *To make these things multi-generational, I think if you're looking for a particular challenge to point out in this report, making them multi-generational requires much more commitment of resources from the universities. Otherwise you just have these charismatic people who are doing it for very little compensation.* **— SJTP ALUM**

SJRC affiliated faculty are based within and financially supported by a home department, and SJRC leaders continuously pursue funding sources, both internal and external to UC Santa Cruz, to maintain SJRC events and programs. In the past, this has included intermittent support from the Office of the President, the Office of Research, the Division of Graduate Studies, and multiple units across campus ranging from the biomolecular sciences and engineering to the humanities. SJRC leaders cited UC Santa Cruz's smaller size as conducive to building these relationships and connecting with campus leaders. The SJRC also receives some funding from private donors.

Having official research center designation from the UC system would allow it to access more UC Santa Cruz funding opportunities, but the SJRC has struggled to obtain this status largely due to its unique governance structure. The UC system is built to recognize university centers and institutes with more traditional leadership models. Most UC Santa Cruz research centers are within the Division of Physical and Biological Sciences and qualify for direct financial support from the university.[75] In contrast, the SJRC is hosted by the Department of Sociology, has designated physical space within the Oaks College, and has been in the process of becoming an independent campus research center for years.[76]

> *To go through the official process of being recognized as an institute, would mean formalizing our governance process. Now*

whether anyone would enforce it or respect it is another issue, but it would give us the grounds, some kind of grounds with the institution to say, 'We need these collective approaches to be respected.' [...] The idea is for it to not be dependent on any individual. The idea is for it to become a set of institutional commitments and practices that endure beyond any individual. Or any collection of individuals that, so it's actually a really interesting project of how to govern it in a way that supports the vision. **—FACULTY**

It's much easier for me to [...] have forged relationships with all the people that I needed to have on board, all the deans, the Vice Chancellor of research, the chancellor, the executive friends, chancellor, all these people who I routinely meet with, the heads of major research institutes on campus, like the Genomics Institute. These are all people who I've had relationships with from the very beginning. **—FACULTY**

The SJRC has adapted its programming based on the availability of funds, staff time, and faculty leadership capacity. A grant from the National Science Foundation enabled the SJRC to establish the Science Justice Training Program. But when NSF funding lapsed, the SJTP had to be reduced to only one seminar and fellows' projects were scaled down to fit within a more restricted budget. To address this, SJRC faculty and staff are currently soliciting external donors to endow the program which would provide stability and enable SJTP to return to its more extensive format. This demonstrates the cyclical nature of funding new initiatives on college campuses. Start up funds for programs are often more available than funding sources that support continued programming. This directly impacts how STEM-in-Society programs sustain themselves and what audiences they can continue to serve.

Program Size and Audience

Cultivating an Interdisciplinary Learning Environment

The SJTP teaches graduate students concrete strategies for navigating the intersection of ethics, justice, and scientific knowledge. Through structured discussions, reflection, and group projects, SJTP fellows "reorient their research questions, methodologies, and goals around questions of science and justice."[77] Annual cohorts are small, ranging in size from 2 to 10 students depending on the year, and there is no disciplinary requirement, so any current UC Santa Cruz PhD student can participate. Building interdisciplinary cohorts is important to the program's design, and program organizers strive to build multi-disciplinary cohorts that include graduate students from both STEM fields and the humanities, arts, and social sciences.

It was very interdisciplinary. I think we had participation from most, if not all, of the colleges at UC Santa Cruz. And UCSC is very interdisciplinary and progressive anyway,

> *so it was really leveraging the culture of the university to do that kind of work.* —**CERTIFICATE ALUM**

Together, fellows build a shared understanding and definition of justice and identify linkages between science, engineering, ethics, and justice before making assumptions about what these relationships might be. Fellowship requirements include a "Science and Justice: Experiments in Collaboration" seminar course, a public engagement project, and participation in SJRC Working Group meetings.[78]

The seminar stresses how cross-disciplinary collaboration is essential for defining the ethical or social justice concerns of scientific research. Fellows are also introduced to different models and approaches to the science/society interface, including interdisciplinary methods that they can utilize in their own research. An emphasis on problem-based inquiry and discussion helps fellows "explore questions of ethics and justice as they arise in their research" and encourages collaboration not only among the fellows themselves but also with faculty and research staff from across UC Santa Cruz and outside of the university.[79]

> *This program brings in students from across the university from the arts, from the social sciences, from biomolecular engineering, from the humanities, who undertake a quarter-long course and introduction to science and justice. The course gives the students a grounding in bioethics and science and technology studies or science, technology and society studies. And we have them form collaborative project groups where they generate research projects, research proposals and projects that they develop and they execute over the course of an academic year.* —**SJRC LEADERSHIP**

The seminar course is typically the first time fellows experience a learning environment with students from other disciplines. To help students learn how to collaborate with experts in other disciplines, they are put in interdisciplinary pairs (e.g., a STEM student is paired with a student from the humanities, arts, or social sciences) to model "collaborative conversations" by exploring a designated topic and designing shared research questions.

The SJRC strives to build meaningful relationships between academic researchers and the publics their work aims to serve and incorporates this into the SJTP by requiring student fellows to design and host a public event that engages local community members in discussion and reflection of a science or technology issue. Working through a public engagement project "allows SJTP fellows to think about how different publics relate to new science and technology on the ground, and to adjust their expectations and projects to the practicalities of their collaborations."[80] Past projects included a community event centered on genetics and DNA testing companies that involved speakers, discussion, and activities at a local venue in Santa Cruz. Another group planned and hosted a single-day conference focused on food systems and food justice. SJRC affiliated faculty mentor student teams as they identify a project topic, design research questions, and facilitate the event. Students must also write an analysis of their project within two weeks of completing their event and ensure the report is publicly available.

> *I loved working with my group where we put together the event. I loved taking a class. I loved the readings, even though they really challenged me. I'm just really, really, really*

> *grateful that I had the opportunity. To me it's like one of the best things I did at UC Santa Cruz, and I was there for a while.* **—SJTP ALUM**

Lastly, SJTP fellows are required to attend 6 SJRC working group meetings or pre-approved SJRC co-sponsored events. Working groups bring faculty, students, and publics together to discuss and address issues of common interest and are a mainstay of the SJRC's community building efforts. Past discussion topics included "genomics and race" and "climate change and development," and meetings range from formal presentations to outdoor walks intended to foster more casual conversations. SJRC working groups provide a physical space for students from across campus to build community across disciplines by participating in cross-disciplinary intellectual conversations and informal social gatherings.

Filling an Education Gap for STEM Graduate Students

Without the SJTP, UC Santa Cruz PhD students would lack the necessary structure and guidance needed to explore interdisciplinary science and technology-related challenges. In particular, SJTP alumni with STEM backgrounds noted that the SJTP helped them explore their preexisting interest in science justice. SJRC and its programs can serve almost as a surprise bonus for STEM PhD students who attend UC Santa Cruz before knowing about the SJRC's certificate program or other offerings.

> *I had never been exposed to the type of theoretical frameworks, the applied work in this environmental justice or actually the science and technology space, quite honestly. So it was all very new to me but very complimentary. I was a practicing civil engineer, primarily working in the environmental engineering space, [...] but frankly I was missing the social science piece in my career.* **—CERTIFICATE ALUM**

> *I've always had an interest in understanding how the science that I am doing broadly intersects with society, the general public at large. I recognize that, especially now, a lot of the things that I study are very niche, and when I try to talk to people about what I do, it's a completely different language for a lot of people, obviously. And I understand that a lot of the things that are associated with sequencing and genomics have broader impacts on society. As a scientist, I feel like I have some responsibility to be able to sort of translate how those technologies can affect people, both in positive and negative ways or in neutral ways. And Santa Cruz, just the environment, was really a good place for delving into these ideas of how my scientific interests intersect with other people's ideas about science.* **—CERTIFICATE ALUM**

Like U-M's STPP graduate certificate, the SJTP demonstrates how STEM-in-Society programs provide academics, including STEM researchers, with dedicated time and physical space to explore the ethics and justice aspects of their research. Alumni enjoyed being a part of an intellectually and socially engaging community that included students from different departments.

> *To have a cohort of students who are all working through the justice questions and their research together, kind of struggling through them and discussing them is really*

valuable because, especially in the STEM disciplines, folks don't have a chance to air the kind of questions about the social and political aspects of their project. They have those concerns, but don't necessarily have a forum in which to discuss them. And so the Science and Justice Training Program gave them the opportunity to work through those kinds of questions in a group of peers. And it was also useful for me in feminist science and technology studies to understand how the technical and material aspects of the projects defined the contours of the research ethics or social justice issues in different ways. So it also made me more attuned to the technical or the scientific components. **—CERTIFICATE ALUM**

Alumni also shared how the SJRC created an inclusive learning environment by including undergraduates, staff, and faculty in SJRC events and discussions which encouraged collaboration with individuals they wouldn't otherwise have working relationships with.

Challenges Providing Interdisciplinary Learning Environments

One of the challenges of bringing STEM and non-STEM students together in the same classroom is that these distinct groups lack a common language they can use to explore new theories and concepts. Navigating STS jargon is challenging for STEM students who have never studied the field before, and even STJP alum with social science backgrounds expressed concerns that the jargon and order of SJTP seminar readings was difficult to navigate. Incorporating real-world examples into course readings discussions can help students understand the contemporary applications of STS and also potentially illuminate careers that incorporate real-world applications of theory to science justice issues.

I do think one of the things that was really challenging for me was all of the different... The theory really blew my mind a little bit. I had never been exposed to that. And so I think having real world linkages to science and technology studies, STS, I think is really important because not everyone that's getting a PhD is going to do theoretical humanities work. We all are going on to different things. And I think my path is just one of many, many paths that could come. I know that there was a guy that was in our program that's doing ethics around AI. Like how cool is that? There are a lot of applied roles that people that come out of that program do land and that could be... It could help students to ground themselves in like well, what could this mean for me when a lot of it is theory in the beginning. **—CERTIFICATE ALUM**

"Incorporating real-world examples into course readings discussions can help students understand the contemporary applications of STS and also potentially illuminate careers that incorporate real-world applications of theory to science justice issues."

STEM-in-Society programs that are introducing students to theoretical foundations in fields that are new to them would benefit from an initial introduction to the structure of readings and strategies for how to approach these readings and field-based communication norms.

> *I don't know how to read this, this is like total mambo jumbo to me. And in retrospect, it was a learning process. I learned a lot by muddling through and struggling with it and realizing like, "Oh, okay, different disciplines have very different, not only different kinds of texts, but different ways for reading those texts." And I have the power to figure out on my own what those are. But I think they could have probably helped me access those texts a little sooner by just like foregrounding them, maybe talking about it at some point, like, "Hey, the goal of this class is for it to be really interdisciplinary, that means you're gonna read kinds of texts that you don't know how to read. And here are some strategies or here are some really concrete [strategies], like note taking or skimming or whatever.* —**CERTIFICATE ALUM**

One SJTP alum reflected that they felt reluctant to ask questions during the fellowship seminar and workgroup discussions because they were in the minority of students without foundational STEM-in-Society training. STEM-in-Society programs that design curriculum intended for students from a diverse array of disciplinary backgrounds must consider how to balance the diversity of preexisting knowledge with learning objectives.

> *One of my really good friends from my cohort was in the class with me as well. But I think we were the only two people who were participating that were coming from the more hard science background. Having more people with that type of background would've been helpful. We always felt like we were in the minority, which was true, and I think it made it hard for us to voice our opinions. I think I was afraid to even say, I don't even know what these things mean sometimes, right? I think I was afraid to slow down the conversation. For any interdisciplinary class, it's difficult, right? 'Cause there are just so many different starting points or backgrounds. So I don't know how to kind of get around that.* —**CERTIFICATE ALUM**

One way the SJRC provides additional support and learning opportunities for SJTP participants was through its other events and optional working group meetings that certificate fellows could attend as a way to supplement their seminar.

> *I won't be the first to admit that it was difficult for me, because I was one of very few people coming from a strictly science background. Whereas other people who were there or were coming from like a social science background, and a lot of them also knew each other, because either they had sort of overlapping interests or things of that nature. So I think it was difficult in the beginning to sort of make those kinds of connections, but the SJRC definitely did a good job of... They had weekly things that people could participate in, like, outside of class. And you know, they were very just I think generally welcoming in terms of, if I had questions about other things.* —**CERTIFICATE ALUM**

Creating accessible and supportive learning environments that serve both STEM and non-STEM students was also a challenge for ASU's SFIS programs with different levels of prior experience with STEM-in-Society fields of study or associated theories and concepts.

Barriers and Incentives to Participating in STEM-in-Society Programs

Like STPP, recruiting students can be a challenge for SJRC. Students have to balance their degree requirements, research obligations, and disciplinary norms of what is an appropriate use of their time or what research outputs should look like. Academic obligations and norms also determine how students allocate their time and can prevent them from pursuing STEM-in-Society training. Interviewees from both programs also attributed recruitment challenges to the disciplinary siloing (and resulting isolation of graduate students within their home departments) that is typical at large research universities.

Most SJTP fellows discovered the program by word of mouth from a student in their home department who had previously participated in the SJTP or who had attended SJRC events. SJTP alumni essentially functioned as unofficial program ambassadors by sharing their positive experiences. This demonstrates the importance of building an alumni base and network that can help provide informal peer-to-peer program marketing.

To recruit STEM students more directly, the SJRC worked with STEM departments to allow STEM students to substitute the SJTP for a required research ethics course. A related incentive to participate was the ability to participate in SJRC offerings before fully committing to the certificate program. Both of these options reduce the additional time burden that students pursuing the SJTP would otherwise have to navigate in order to participate.

> *We had an ethics requirement. And this class that was a part of the program could also replace the ethics requirement. So that helped to make the decision [to participate] more straightforward.* **—CERTIFICATE ALUM**

> *I liked that it was a low commitment at first. As a beginning graduate student, I had actually never taken a sociology class before, and so I felt very interdisciplinary but also very unsure of navigating grad school, and where my niches would be. So the setup of the science and justice program allowed you to take classes without committing to the program and see if it would work for you. And I really appreciated the balance of not just trying to chug students through the program but making sure it was a good fit and it would align with some of your interests.* **— CERTIFICATE ALUM**

Another way STEM-in-Society programs can attract prospective students is by offering financial incentives for participation. When the SJTP was initiated, its National Science Foundation funding included financial compensation for students who completed the certificate in the form of a partial tuition waiver. At that point, the SJTP's time commitment was bigger, with students being required to complete two seminars, and the financial incentive made the program more appealing to prospective students.

> *I was looking to compliment my technical expertise with some social justice, environmental justice expertise. I also, of course, was enticed because the fellowship did pay for a little bit of my schooling.* **—SJTP ALUM**

While this model was successful in the early stages of the program, seed funding opportunities

are temporary, and programs that cannot afford to financially support fellows or students develop other incentives for participation. When the NSF funding lapsed, the SJRC was no longer able to financially compensate students for their participation. One way the program has adjusted is by decreasing its seminar requirement from two to only one seminar.

Professional Development and Career Outcomes

The SJTP helps students learn important collaboration skills that they could carry with them in their careers. SJRC faculty demonstrate how to work respectfully across disciplines, and fellows' group projects help students practice collaborating across disciplines. SJTP learning outcomes were similar for both STEM students and fellows pursuing graduate degrees in the arts, humanities, or social sciences. For many of the latter, pursuing the SJTP was a natural progression of their preexisting interest in social justice. The SJTP's cross-disciplinary emphasis helped these students understand the realities, including the challenges and benefits, of interdisciplinary work.

> *One thing that I noticed in SJRC was the faculty were always really respectful of one another. You could also have a dissenting view from the faculty and one another. And it was heard, it was allowed, it was understood and if it wasn't understood, you ask each other questions.* **—CERTIFICATE ALUM**

> *In reflecting back, the class that we had to take before agreeing to be Fellows was a huge interdisciplinary mashup. I think we had a microbiologist with us and there were a lot of social scientists, and as a second year graduate student, I was very pie in the sky thinking, well, interdisciplinarity is so easy, it's so easy to talk with people. But that class really showed how some conversations are actually really difficult to have across disciplines. And it takes work and it isn't as easy as it may seem at the start. And so, having practiced talking about big issues around science, even objectivity in science was a big hot topic issue in this class discussion. And I think navigating those discussions has really helped me in thinking and actually in doing my dissertation and talking with people who aren't social scientists, but being able to find a common ground.* **—SJTP ALUM**

The SJTP also helped students hone their communication skills so they become more confident and skilled in translating their research to both academic and non-academic audiences. Being able to practice communication skills is especially important for students impacted by the COVID pandemic because they missed out on many opportunities to pursue research communication.

> *The last three years have been quite challenging for many. We have students, not just undergrads, but grads who struggle with communication, interpersonal communication, who struggle with putting themselves out*

> *there, putting their work out there. And we know this is a vital part of graduate professionalization. [...] So bringing students together, facilitating a process in a space that allows them to externalize their interests, and then take those interests and collaboratively cohere them into a project that values everyone's input equally, and that encourages it in ways that build accountability into the project, but also deepens their ability and allows them to begin expanding the breadth of their professional networking capabilities.* **—FACULTY**

Teaching students better communication skills is also important because STEM-in-Society programs can have even greater ripple effects when SJTP alumni participate in, and contribute to, regional, national, and international events and organizations. By weaving justice through their work and sharing their process or outcomes, SJTP fellows promote best practices in science justice to regional working groups, regional collaboratives, and professional networks and associations.

> *I have drawn on a lot of what I learned during the science and justice fellowship. And so what has that looked like? That has looked like developing equity best practices for engagement citywide for our entire organization. It has resulted in compensated equity advisors on our climate action plan using tools like equity screening tools, equity capacity readiness assessments and other tools to really understand and help us to prioritize our work with frontline communities and groups.* **—CERTIFICATE ALUM**

Similar to STPP alumni's experiences, having a STEM-in-Society certificate can boost SJTP fellows' professional marketability and change their career trajectories. The SJTP certificate is a credential they can highlight on their resume or CV to demonstrate their competence in science justice and help them be competitive when applying for justice-related opportunities. For example, earning the SJTP certificate helped one alum secure an early career opportunity hosted by a professional association in their field of study.

> *It's useful to have a credential in science and justice, both for people who are working in feminist science and technology studies or on science from a social sciences and humanities perspective, and for people in the STEM fields. Because it shows competency in approaching questions of both science and social justice or research ethics together.* **—CERTIFICATE ALUM**

The SJTP has impacted alums' future work by ingraining an interest in, and professional emphasis on, environmental justice. Some SJTP alumni have pursued specific work opportunities based on their solidified interest in, and commitment to, science and justice issues. These alumni have gone on to incorporate critical perspectives learned during the SJTP into their work. Some SJTP alumni who are now faculty at other universities have tried to replicate programs similar to the SJTP in a new context, often with mixed results. Recreating one STEM-in-Society program's model at another institution proves challenging for a myriad of reasons, including differences in institutional culture, different student audiences, and different faculty obligations. Supporting STEM-in-Society programs requires identifying and understanding the institution-specific contexts, and challenges, that make it difficult to establish, maintain, or grow these programs.

> "Recreating one STEM-in-Society program's model at another institution proves challenging for a myriad of reasons, including differences in institutional culture, different student audiences, and different faculty obligations. Supporting STEM-in-Society programs requires identifying and understanding the institution-specific contexts, and challenges, that make it difficult to establish, maintain, or grow these programs."

When I was looking for post-docs, I was looking for labs where there was some level of trying to understand why are there health disparities in these genetic diseases that I'm interested in. So that's I think one of the main reasons why I joined this lab. **—CERTIFICATE ALUM**

It made a very big impression on me, and really it actually changed how I approach my work and the course of my work. I'm extremely focused on environmental justice in my work, and I would not be had I not been part of that program. **—CERTIFICATE ALUM**

I really believe in this model of using science and technology studies tools to help researchers across the humanities, the social sciences, and STEM, to be able to think more concretely about how their research intersects with social justice. It was a great model for me early in my career and one that I hope to continue and advocate for, because I think the insights from this field can be useful in a lot of different arenas, and as scholars we're not always good at finding those places and making ourselves heard. **—CERTIFICATE ALUM**

The impact the SJTP has on graduate fellows demonstrates how a relatively small commitment to STEM-in-Society training can provide big pay-offs for alumni worldview, careers, and professional values. The SJRC would like to extend these benefits to new audiences by expanding its programs in the future and continuing to build cross-campus relationships and collaborations.

Emerging Opportunities and Challenges

Expanding Program Reach by Serving New Audiences

Thus far the SJRC's training programs have focused primarily on graduate students, but UC Santa Cruz's undergraduate-focused education

mission and growing interest in science justice presents an opportunity to offer undergraduate STEM-in-Society training. The SJRC wants to create a program similar to SJTP that reaches students earlier in their academic experience and professional careers.

> *There's a lot of opportunity to bring in undergraduates into the program, 'cause I heard from a lot of undergraduates that they were really interested in what they were doing but didn't know how or where or if they could get involved. There's a lot of interest with undergraduates thinking about justice issues and science.* **—CERTIFICATE ALUM**

A new partnership with the Department of Critical Race and Ethnic Studies includes a science and justice hire who is expected to help the SJRC increase its capacity to reach undergraduate students by contributing to the development of an undergraduate science and justice minor. [81]

> *Our first science and justice hire at the university is in Critical Race and Ethnic Studies, and CRES is a great partner for us because they also have, as the core commitment, a founding commitment of the field of critical race and ethnic studies, at least as it is practiced here at Santa Cruz is questioning the very institutional formation of the academy. So who's in, who's out? Whose interests are represented. [...] and CRES as well as Science and Justice has a real focus on including our students from undergrads to, to postdocs, in the process of giving us feedback and thinking about, you know, what we're doing.* **—FACULTY**

Creating and filling this position was a landmark moment for the SJRC because it required leadership buy-in across the physical and biological sciences and the humanities. SJRC leaders also hope that establishing a new position like this will continue to help build a UC Santa Cruz that values interdisciplinary science and justice scholarship. Hiring faculty with interdisciplinary backgrounds or supporting cross-departmental faculty positions is one of the ways STEM-in-Society programs can strengthen their interdisciplinarity and broaden viewpoints of what it means to be a science and justice researcher.

Building a Culture of Interdisciplinarity at UC Santa Cruz

SJRC leaders are committed to creating an interdisciplinary and collaborative UC Santa Cruz culture and invest time and effort into building relationships across disciplines across campus. However, establishing new cross-campus working relationships, transforming individual perspectives, and shifting UC Santa Cruz's culture is a slow process. As with other STEM-in-Society Programs, disciplinary biases create a perceived hierarchy of sciences that positions STEM fields as more legitimate and more rigorous than the social sciences. This makes it difficult to build working relationships between humanities, social sciences, and STEM fields.

One interviewee illustrated how disciplinary bias can manifest for STEM faculty in SJRC working groups even though they are carefully designed to foster interdisciplinary discussion and collaboration.

> *PIs in the STEM fields [...] have to manage their grad students and postdocs, publish,*

> *run the lab, [...] getting them to come and to stay is a real challenge. And often we would get STEM faculty come and they would hear a talk from a social scientist with a bunch of jargon or Foucault quotes or whatever, and they just get frustrated and angry. They're like, "I don't know what's happening here*

Wayne Hsieh

> *and I should be able to understand it and this and that." And it's like well, if I went to one of your talks and you were talking about amino acids or whatnot, there would be some stuff that I wouldn't understand, but I would be kind of chill with that because it's not my field. And I would put up my hand and ask some questions about it. [...] So there were two problems. There was this time and space aspect, and then there was this imagined hierarchy of disciplines in which STEM faculty felt everything should be transparent to them because they were on the top of the hierarchy.* **—CERTIFICATE ALUM**

STEM faculty at UC Santa Cruz have little time, tools, or incentive to work through the challenges of interdisciplinarity. This partially signals the importance of STEM-in-Society training at earlier stages of researchers' academic careers, before field-based norms and hierarchical beliefs about the value of different disciplines become deeply ingrained assumptions.

> *When we're talking about interdisciplinarity, we need scientists working together with social scientists, you've gotta start early. You have to have the training before people reach the assistant professor stage. Because it's important to have the training, and it's important to have that kind of exploring ground that you have in grad school to be able to think about those issues. Because then you're, as soon as you have a job as an assistant professor or a PI, you're in publish or perish mode. And then it's really difficult to create the space and the time to explore these things because you can't just add justice and stir.* **—CERTIFICATE ALUM**

Co-designing courses is one way STEM and non-STEM faculty can leverage their shared expertise for the benefit of students earlier in their research careers. Like Virginia Tech faculty who have co-designed hybrid STS-STEM courses, SJRC affiliated faculty from the Department of Sociology and UC Santa Cruz's Genomics Institute have co-designed a bioethics course. This work requires a good deal of effort for SJRC faculty, but they are committed to changing the culture of UC Santa Cruz to one that not only values science justice but one that makes it an integral part of students' education. This highlights the difficulties STEM-in-Society faculty face when attempting to broaden campus impacts. Often these efforts lack incentives and rewards, apart from their own commitment to the public interest.

Broader Contributions to STEM-and-Society

As with Virginia Tech STS, growing interest in STEM-in-Society issues and funders' responsible research requirements have benefitted the SJRC by highlighting its faculty's expertise and creating opportunities to collaborate across UC Santa Cruz and leverage funding. SJRC faculty described how NSF and National Institutes of Health (NIH) funding opportunities that require ethics components are creating demand for science and justice expertise.

> *There's been an increasing pressure to bring more science and engineering research to the campus because it pays the bills through the overhead from the grants. Now, what has helped us in that moment is that increasingly the funding agencies [NSF and NIH] require ethical social analysis and research. And we are recognized nationally and internationally as doing leading work in that area. Which means we have been able to get the support of our administration because I think they see the benefit, the broader benefit to the campus. If only you're looking at the narrow issue of how do we get large research grants here? Because science and justice does not only just bring in its own grants, which it has, but it's key to getting large NIH training grants. So we've been on several multimillion dollar large NIH training grants that needed a second responsible conduct research component.* —**FACULTY**

SJRC is also committed to shifting how STEM researchers at large universities approach STEM-in-Society collaborations. SJRC is creating a practical guide that provides STEM researchers with best practices for collaborating with arts, humanities, and social science experts. Funded by NSF, the Leadership in the Equitable and Ethical Design (LEED) of STEMM[82] Research project will "create guidelines for the design, coordination, implementation, and dissemination of STEMM research that integrates DEI[83] and ELSI[84] in a manner that leads to more equitable and just science and technology."[85] UC Santa Cruz, via the SJRC, is one of six universities involved in this effort, which emerged from the need to address the lack of consistency in how STEM and non-STEM academics engage with each other when attempting to collaborate on projects.

> *The research component will lay out guidelines and best practices for how social scientists, humanists, artists, scientists, and engineers practically come together on grants to work together. There's all this demand for it, but there's no criteria for it. And the SJRC decided we needed criteria. Because it has happened that scientists and engineers will really wanna work with us and will talk to us about how important our work is. They'll get us in the grant proposal, they'll get the grant, and then all of a sudden we're no longer that important anymore. So we want to intervene in that and, and ensure accountability to the project of really working on science and justice.* —**SJRC LEADERSHIP**

The SJRC has also shared insights from its own program history to contribute to a broader discussion and offer one model STEM-in-Society training model. Together, SJRC faculty, staff, and students have published journal articles sharing the benefits of the SJTP as well as the challenges associated with implementing a justice-centered science program within an institutional system that inherently emphasizes siloed outcomes and

independent work.[86]

> *We just did a review of a lot of different programs and what they were doing. And we did conclude that there wasn't really anybody who had the focus that we had on questions of social justice where we really are foregrounding questions of power, questions of colonialism and racism and gender discrimination at the heart of it, and a commitment to change. So practice, so changing institutions. I do actually think we're pretty unique in that.* **—SJRC LEADERSHIP**

Sharing lessons learned can help other STEM-in-Society programs reflect on their own practices and also illuminate the benefits of these training programs for funders.

Summary

The SJRC demonstrates how a STEM-in-Society program can have positive impacts at multiple scales. Individual students who complete the Science and Justice Training Program are equipped to interweave justice considerations in their work, learn how to navigate interdisciplinary collaborations, and form a professional identity that is closely aligned with justice values. By intentionally inviting faculty, students, and staff from across typically siloed disciplines, the Science and Justice Research Center also provides a convening space for UC Santa Cruz that has resulted in more interdisciplinary collaborations and the university's first STEM/science justice faculty hire. At the broader community level, the SJRC convenes campus and off-campus community members and encourages interaction and discussion of the social justice aspects of contemporary science or technology issues. The SJRC has also contributed to the STEM-in-Society field by publishing reflective articles that demonstrate their approach to STEM-in-Society graduate education.

However, it remains difficult for SJRC to secure consistent funding, build leadership capacity, and maintain a unique advisory structure that doesn't fit the mold of UC Santa Cruz's other research centers. The SJRC highlights that while STEM-in-Society programs can use creative administrative frameworks and leadership models to support their unique missions, it can be challenging to find common ground within a university setting that requires more traditional leadership models to become a fully realized center or institute. Additionally, while SJRC affiliated faculty have been successful in securing a range of funding opportunities, the certificate program was modified to work within the confines of less funding following the expiration of initial seed funding. SJRC's success can be largely attributed to a single founder/leader, and SJTP alumni noted that the Center's longevity and sustainability was largely reliant on maintaining its director. And finally, the SJRC's non-hierarchical leadership model makes it challenging to become an official UC Santa Cruz research center.

Despite these challenges, the SJRC fosters scientific research that has meaningful broader impacts through careful community engagement and consideration of justice issues.

The Science and Justice Research Center at UC Santa Cruz is unique in its emphasis on creating intentional spaces for scholars and students from different disciplinary backgrounds to come together to co-discover intersections of science and justice and reflect on the justice and ethical aspects of their own work. SJRC leaders have intentionally built the Center's activities, certificate program, and cross-campus collaborations with the aim of creating a campus culture that is more conducive to interdisciplinary work and science and technology justice.

CASE STUDY

School for the Future of Innovation and Society at Arizona State University

HIGHLIGHTS

- The ASU president's connection to the School for the Future of Innovation in Society's (SFIS) has driven its evolution from a research center to a fully-fledged School that hosts undergraduate and graduate education programs.
- ASU's inclusion-centered public education model requires SFIS to justify the value of a STEM-in-Society degree to both prospective students and their parents.
- SFIS must compete with ASU's more traditional and recognizable degree programs to increase undergraduate student enrollment.
- The lack of attention paid to SFIS degrees by centralized campus student recruitment staff puts additional pressure and burden on SFIS administrators, faculty, and staff who are not trained in marketing or student recruitment strategies.
- SFIS's commitment to multidisciplinarity in the form of loose PhD requirements leaves some students craving more structure, including methodological guidance.

History and Institutional Context

The School for the Future of Innovation in Society (SFIS) at Arizona State University (ASU) demonstrates how a STEM-in-Society program can evolve from a research-centered think tank into an education-centered campus unit. SFIS also illustrates the challenges that can arise for STEM-in-Society programs based at large higher education institutions that serve a range of audiences, each with unique needs, expectations, and career outcomes.

While SFIS was officially established in 2015, it began as the Consortium for Science, Policy and Outcomes (CSPO).[87] CSPO was an independent think tank founded by science and technology policy scholar Michael Crow that became a part of ASU when Crow became university president in 2002. Initially, CSPO was a research endeavor with no degree programs. In 2007, CSPO faculty designed and established a PhD program to bring in graduate researchers to support a growing research agenda. Since then, ASU, through SFIS, has grown to offer more STEM-in-Society degree programs than any other university in the United States. This includes a diverse assemblage of undergraduate minors and majors, master's and doctoral programs, and graduate certificates.

Major restructuring at ASU has, and continues to, impact SFIS. For one, ASU created the Julie Ann Wrigley Global Futures Laboratory® (GFL) in 2019 which functions as a campus within a campus by emphasizing use-inspired research, sustainability, and global community service.[88,89] The GFL serves as the overarching coordinating body for a new College of Global Futures (CGF) and multiple research centers, including CSPO. Through this transition, research centers like CSPO no longer administer or confer degree programs, necessitating the creation of SFIS to house CSPO's growing education portfolio. The CGF now houses four schools: SFIS, Sustainability, Complex Adaptive Systems, and Ocean Futures. Its new status enabled SFIS to expand its education offerings and grow its faculty through a combination of external hires and recruiting faculty from other ASU schools or departments. SFIS's highly interdisciplinary faculty brings expertise including, but not limited to, science and technology studies, engineering, English, business, and global development, and SFIS maintains a 1:3 faculty to student ratio.

The direct connection between ASU's president and CSPO (and by default, SFIS) certainly helped sustain these programs through major administrative restructuring. However, the impacts of these major campus-level changes on SFIS and CSPO are still playing out as campus leaders continue to navigate this reorganization. Our analysis focuses on SFIS, including its diverse set of education programs, and how its culture and broader university characteristics impact its operations and student outcomes.

ASU is a Hispanic-serving institution committed to making higher education accessible for all. To carry out this vision and recruit a student population that reflects Arizona demographics, ASU built a large online campus and expanded its four campuses in the metro-Phoenix area. As a result, one-third of ASU undergraduates are first-generation college students, and ASU is consistently the largest public higher institution in the United States with 114,484 undergraduate students, 31,171 graduate and professional students, and 5,300 faculty members.[90]

> *SFIS's program offerings and its adopted motto, "The Future Belongs to Everyone," directly reflect ASU's inclusive vision for higher education.*

> *The underlying objective of our efforts in the educational space has been to open up, diversify and make more inclusive access to the knowledge and skills that one would need in order to participate in technological leadership in contemporary societies. And particularly for those folks who do not want to pursue that through an engineering approach and an engineering degree. Every technology enterprise on the planet has lots of engineers but it also has lots of people. And our interest*

> *is in broadening that group of perspectives, values, cultural backgrounds, experiences that we bring to technological leadership in our societies.* —**FACULTY**

However, the fact that ASU serves a large and diverse student body places unique pressures on SFIS. Faculty must navigate the unique challenges of recruiting first-generation college students while simultaneously competing with ASU's many other degree programs. This is particularly challenging at the undergraduate level and, as we discuss further in this case study, has created growing pains for SFIS as the school navigates its new position within the College of Global Futures. To make its programs available to a wider range of student audiences, SFIS offers both in-person and online degrees, and leverages ASU's history of virtual courses to offer flexible hybrid and remote options for students in the late stages of their graduate degree programs.

Program Size and Audience

To serve this varied audience, SFIS offers a range of degree types and formats at both the undergraduate and graduate levels. While its two PhD programs and the Global Technology and Development MS program are relatively large, its undergraduate enrollment—particularly in comparison to its counterparts across campus—is low. This is expected considering that SFIS began as a research center that historically emphasized financially supporting graduate researchers and recruiting PhD students. In contrast, its undergraduate programs are relatively new. This poses an existential risk for SFIS, however, as undergraduate tuition is necessary to ensure continued funding. Furthermore, as we discuss further in later sections, student recruitment is challenging.

SFIS has grown its degree programs through a combination of ground-up design and acquiring preexisting programs over the past nearly 20 years. In 2007, CSPO established the PhD in Human and Social Dimensions of Science and Technology to produce graduate researchers for its NSF-funded Center for Nanotechnology in Society, but its scope has since expanded considerably.[91] The PhD program equips students with social science and humanities tools to understand science and technology. Due to SFIS's size and the breadth of its educational offerings, we focus primarily on its undergraduate bachelor's degree and doctoral degree programming.

Student Enrollment and Marketing Challenges

From a student enrollment perspective, SFIS's challenge is not wholly unique; it must recruit undergraduates to benefit from tuition dollars and justify its existence to the university. However, few students come to college knowing about STEM-in-Society as a curricular option or career path. SFIS competes with other degree programs for prospective students, and longer-standing programs typically have graduate employment track records they can rely on to justify their degrees to potential students. As a newer campus unit with younger degree programs, SFIS has limited alumni employment data to demonstrate

TABLE 5. Education programs offered by the School for the Future of Innovation in Society during 2023-2024 school year.

AUDIENCE	TITLE	DEGREE	FORMAT	YEAR ESTABLISHED	2023-24 ENROLLMENT
Undergraduate	Innovation in Society	BA	in-person or online	2016	24
Undergraduate	Innovation in Society	BS	in-person or online	2016	26
Undergraduate	Innovation in Society	Minor	in-person	2016	3
Undergraduate	Innovation for Impact	Certificate	in-person	2016	0
Graduate	Global Technology and Development[92]	MS	in-person or online	2012	47
Graduate	Public Interest Technology	MS	online	2020	17
Graduate	Futures and Design	MS	in-person or online	2022	3
Graduate	Human and Social Dimensions of Science and Technology	PhD	in-person	2007	36
Graduate	Innovation in Global Development	PhD	in-person	2015	41

Source: School for the Future of Innovation in Society, Arizona State University

graduate salary outcomes or potential career paths. As a result, SFIS, like many other STEM-in-Society programs, struggles to convey the value of its undergraduate degrees.

Prospective students are typically looking for the best investment for their future. This is especially true for those ASU is eager to attract: first-generation college students and individuals in lower income brackets. For first generation college students in particular, higher education is a daunting financial commitment. Therefore, these students are more likely to pursue a recognizable degree with demonstrable career pathways, positive employment outcomes, and clear salary outcomes. Marketing an "Innovation and Society" degree, for example, particularly in a university of ASU's size, is difficult. Furthermore, campus-level student services staff often don't know how to market SFIS degrees.

In addition, campus initiatives designed to support students can unintentionally exacerbate enrollment challenges. For example, all ASU undergraduates

must declare their majors before beginning their first semester. This increases competition for students' commitment to a degree program before they even officially start their higher education journeys. Additionally, students use an online degree audit system to track their progress, and, while this tool is designed to help them make informed course selections and stay on track, it also reduces degree exploration. Exacerbating this, larger degree programs receive more marketing support from ASU's centralized campus admissions and student services staff who recruit high school students and work with incoming students.

Leadership transitions during and after the COVID pandemic, both within SFIS and for the College of Global Futures, also exacerbated these enrollment challenges, as there was no consistent guidance on program identities or curriculum planning and forming program identities.

> *We took some hits during the pandemic. There was leadership transition, there was institutional transition and so the MSTP program was always relatively small and had a bit of an identity issue being a policy program that was not in DC. And we were trying to grapple with that and figure out how much DC we could and should incorporate and how much we might need to twist our curriculum a little bit to deal with local and regional issues in the Southwest and Intermountain West.* — **FACULTY**

There also may simply be a ceiling on the number of students seeking the kind of inclusive and future-focused solutions to complex problems that SFIS and STEM-in-Society Programs provide. When SFIS launched a Public Interest Technology master's degree program in 2020, for example, enrollment in its Science and Technology Policy MS degree declined. As a result, SFIS recently paused the Science and Technology Policy MS degree due to low enrollment. Nevertheless, SFIS is under pressure to increase enrollment, regardless of how their enrollment levels compare to peers at other universities.

One way to respond is to help administrators understand that while STEM-in-Society programs around the country may have low enrollment—with SFIS's numbers higher than most—they perform an important service to the university community (including faculty, staff, and students) on how to conduct responsible research and innovation. But if increased enrollment is the goal, then these programs need additional support from specialized student recruitment and advising, as well as career services staff who understand the benefits of an interdisciplinary STEM-in-Society education and related career opportunities. STEM-in-Society program leaders can help them by clearly identifying their degree program's learning goals and tracking alumni career pathways. They may also decide to limit their degree offerings, to reduce competition among them as well as other opportunities on campus.

Despite these challenges, SFIS successfully recruits undergraduates by offering courses that fulfill university requirements for a variety of majors.[93] Students often discover SFIS and its unique approach through courses they take as an elective that sounds interesting to them, and/or to fulfill a general education requirement.

> *There are a wide variety of university requirements you have to meet. You can't simply finish an undergraduate degree in a year and a half. But, if you've been wandering around the university, you've bounced around, you thought you wanted to be an engineer,*

> *then you thought you wanted to be a business major, then you thought you wanted to be a design major and you stumble onto us in your junior year, it's actually possible to finish our degree program in that amount of time.* —**FACULTY**

In this way, students who might be thinking about changing majors or adding a double-major discover that they can change (or add) a new SFIS major and still finish their degree(s) in 4 years. Interviewees also noted that students from technical programs, including engineering, are often attracted to SFIS as they realize their interest in technology or technical problem solving isn't being fulfilled by a more technical degree program. Additionally, the high faculty to student ratio offers smaller class sizes, more direct faculty mentorship, and better access to applied research opportunities.

SFIS also attracts both undergraduate and graduate students by offering multiple degree pathways including in-person, online, and accelerated degree options.[94] These efforts have been successful. When SFIS first established its Innovation and Society degree programs, enrollment grew to 60 students very quickly. While this is smaller than other ASU undergraduate programs, it is large compared to other undergraduate STEM-in-Society programs in the United States. Under the accelerated program option, students can earn both a Innovation and Society bachelor's degree and a master's degree (in either Global Technology and Development or Public Interest Technology) in five years. This broadens SFIS's student pipeline and is of particular interest to students who may not have considered pursuing a graduate degree due to time and financial constraints.

Being a part of the new College of Global Futures gives SFIS undergraduates access to academic advising through the CGF's Student Services Center.[95] The CGF also works with community colleges to recruit students transferring to ASU from another university or college. These new services should help with student recruitment because the staff will be more familiar with SFIS offerings and potential career outcomes and can relay this to prospective students. This demonstrates the importance of scale when it comes to providing career services. SFIS students need career services staff who understand the unique and nuanced differences between education and career outcomes for students coming from the different schools within CGF.

> *Now that we are in a college, we have college career services, but this is the first year that we've heard from those career services and heard what they're offering to our school, so that is something that is really exciting. We just had our first Career Day last week, so we are building up a career apparatus as a college, and the College is listening to the School to understand how what we do is distinct from... Sustainability.. is distinct from Ocean Futures.* —**FACULTY**

Most STEM-in-Society programs lack this resource and therefore must take extra steps and put in more effort than business schools or engineering departments that have consistent relationships with recruiters who frequently come to campus to recruit their graduates.

Interdisciplinarity and Program Flexibility

SFIS has a highly interdisciplinary faculty, coming from political science, business management, climate adaptation, informatics and computation sciences, engineering, global development, and the arts. While this can often lead to tensions in a higher education environment, SFIS has intentionally developed a shared culture that values different perspectives and approaches to problem solving. Interviewees consistently commented on the degree of collaboration and respect for different academic backgrounds and the belief in interdisciplinarity to solve problems and create better futures. This orientation has had a large influence on how SFIS has designed its degree programs. At the graduate level, it provides flexible options for students with varied subject matter interests, professional obligations, and time constraints. Current graduate students and alumni alike noted multiple facets of program flexibility that attracted them to SFIS, especially the ability to obtain their degree online, pursue interdisciplinary interests, and tailor their degree program to their career goals.

While providing students with disciplinary flexibility is an asset for SFIS, it can also result in challenges for students seeking more structure. For example, the Human and Social Dimensions of Science and Technology (HSD) PhD program has limited course requirements.[96] In contrast to EPP and Virginia Tech which have extensive coursework requirements, it only prescribes two courses to its PhD students.[97] While this flexibility enables students with prior research experience or a clear research topic in mind to self-select their courses and research focus, it can be paralyzing for students who are less specialized and at an earlier stage in their careers. These students crave basic theoretical and methodological grounding. SFIS students and alumni from the HSD PhD program, for instance, reported a disconnect between program requirements and what they described as faculty members' laissez-faire mentality regarding research method training. The program has no core methods requirements beyond an introductory research methods course and instead encourages students to obtain relevant training through their chosen (and highly flexible) "major and minor fields." However, this can produce inconsistent learning outcomes.

> *The students that I see succeeding, they either have the disciplinary background or there's somebody on their committee, oftentimes outside of the school, who's really working overtime to make sure they got methods and has a vision for what a trained student looks like and is actually monitoring their progress.*
> **—HSD PHD ALUM**

One way HSD PhD students are encouraged to navigate this is by taking courses outside of SFIS and including non-SFIS faculty on their committees to build an advising team that provides the best combination of research advising and mentorship. The expectation is that students will utilize the two foundational courses and additional training to construct their dissertation research.

> *SFIS was designed with the inputs of faculty from many different units across this university environment, which is by design deeply interdisciplinary. And so one of the strengths of this PhD program is that students are not limited to saying that you can only engage faculty for your committee from this one school. Quite the contrary, the vast majority of our PhD students have dissertation*

> *committees, comprising individuals from multiple units on campus and sometimes even beyond ASU. And we do have a mechanism for admitting those folks to serve on a PhD committee. So I would say that's a real strength.* **—FACULTY**

However, students felt that because they could essentially choose their own learning path, they lacked a consistent theoretical framework to analyze and solve problems. This left them feeling that there was a mismatch between their desire to gain a concrete, consistent set of skills and SFIS faculty members' focus on academic research. For some students, the absence of requirements made it difficult for them to design independent research projects and complete a dissertation that met their review committee's standards. A student with a strong academic background and/or previous research methodology experience is more likely to be able to successfully design the required second year research project (and ultimately their dissertation) than a less experienced student who has no formal training in research designs and methods.

> *I think the other challenge was that… And I think this is with a lot of interdisciplinary programs, is if you are too interdisciplinary or you have too much independence, I think that works for students who already are focused or already have enough of a roadmap of what they want to do. But I think for a lot of students coming in without that experience or knowledge, it's too much and there's not enough guidance or instruction. And it's very easy to just be pulled in so many different directions.* **—CURRENT STUDENT**

Ultimately, students must be well-prepared to take advantage of the enormous interdisciplinarity SFIS offers in its PhD programs. Otherwise, it can lead to longer degree completion timeframes and reduce competitiveness for both academic and non-academic positions.

Professional Development and Career Outcomes

STEM-in-Society Graduates Need Specialized Career Guidance

As with EPP and Virginia Tech STS, SFIS's interdisciplinarity and PhD program flexibility can make it difficult for its students and alumni to identify and secure their professional niche. Like other STEM-in-Society graduates, SFIS students and alumni struggle to fit into traditional disciplinary molds that universities tend to uphold.

> *Because everyone is doing something different, especially faculty-wise, it gets a little bit hard to get a hold of them [faculty] and know what they're doing. So creating that sense of community and even just explaining what the school does… It gets a little bit hard. […] Lots of people are doing their research and so they're in the field and other people are*

> *online only. Other people are in DC. So it's a little hard to have a sense of community and just be like, "Yes, this is. I know what I'm doing here. I know where my place is." A conference that I attended, a professor asked me, "Okay, so what program, what department would you be in eventually?" And I was like, "I don't know." I had no answer. She was like, "Economics, politics? I was like, "Umm, uh... " [laughter] So I feel like that could be better, just like having a clear sense of belonging.* —**CURRENT STUDENT**

Challenges like these can be addressed with increased attention to professional development. Students seeking non-academic employment, for instance, could be better connected to SFIS alumni and/or CSPO faculty and staff who can provide non-academic career guidance.

> *The fact that we have a lot of collaborations within other places, not just within the school. We have a lot of faculty that share their appointment with other schools. [...] We have CSPO, which is in DC, and now we have a DC branch for SFIS where there's classes and things like that. So it takes time and it can be a little bit overwhelming 'cause there's so much going on. But that's also cool because you can get to network outside of just academia and you get more opportunities to just see how, like the different paths that you can actually take with the degree.* —**CURRENT STUDENT**

STEM-in-Society graduates tend to break professional molds. Their interdisciplinary training requires increased career support that academically-trained faculty cannot always provide. Connecting students with professionals they can network with and learn from is one way STEM-in-Society programs can support students seeking non-academic careers.

Emerging Opportunities and Challenges

Navigating University Restructuring and Clarifying Program Identity

SFIS is characterized by a history of transition in a constantly changing landscape. As a result, it has been difficult to pause and take stock as its roles and responsibilities have increased to include diversified educational programs and related student recruitment and advising. Joining the CGF required SFIS to develop a new identity and marketing strategies, but it also now has access to more shared resources. It has experienced diminished student enrollment, initially triggered by the COVID pandemic. Finally, shifts in faculty members' roles and responsibilities, including interim leadership within SFIS for several years, have led to the postponement of internal degree program assessment and long-term degree planning and programmatic decisions.

As we have discussed throughout this case study, SFIS, like many STEM-in-Society programs, serves a diverse array of students not only in terms of expertise and area of focus but also in terms of their professional preparation and career goals. This can create confusion and dissatisfaction, particularly if there is a mismatch between expectations and outcomes. One interviewee reflected that, in hindsight, SFIS should have spoken with professionals working in innovation and policy professions, including SFIS graduates who are now working in science and technology policy, before creating new undergraduate majors. They could, for instance, have tapped into SFIS alumni's professional knowledge and experience and asked which aspects of their SFIS education prepared them for their position and skills they are looking for in new hires.

> *I would have done a more systematic investigation of the careers that we envisioned our students going in and sort of back-casted the competencies for those careers [...] at the undergraduate level, this cannot be an intellectual degree. I mean, yes, we can inflect it with these really great big ideas, but at the end of the day, we need to understand how the rubber meets the road in terms of what our students will do when they graduate.* —**FACULTY**

In addition to inconsistent learning outcomes for doctoral students, SFIS interviewees reported inconsistencies in terms of students' access to positive faculty mentorship.

> *We don't really know what the program's vision is in itself. I understand that the PhD journey is always solitary and it depends upon how you craft your journey with your advisor and your dissertation committee. But as students, we don't really know what we are going to get out of this program at the end of my four or five or six years. So, will I be able to write a complete NSF grant? I don't know. We don't have a deliverable.* —**CURRENT STUDENT**

STEM-in-Society program alumni can help fine-tune program design and desired learning outcomes and clarify expectations. In general, higher education program alumni are an underutilized source of information regarding what skills and knowledge are important in professional spaces. Relying on alumni seems even more important for SFIS given that its degree programs emphasize problem solving to build better futures. This is a quickly changing field with relevant skills shifting as new science and technology problems emerge.

In addition to reflecting on program strengths (e.g., employability and career success of PhD program alumni), interviewees also cited the need to critically evaluate and reflect on what degrees SFIS should continue to offer or add in the future. Interviewees, students and faculty alike, recommended that STEM-in-Society programs consider the purpose of doctoral degrees and if a PhD is necessary for students to achieve their desired learning outcomes or career objectives.

> *I think HSD in particular has a problem of trying to admit people that are great candidates for master's programs, but are not great candidates for PhD programs. And so you have this, you have a lot of people that they're approaching year 12 of PhD and they're not even done with comps yet. So that you have these forever people. And so I think there's a problem of not having a standard of admission, which is weird 'cause I'm at ASU. I don't believe in elitism for institutions, but for*

> *PhDs, I think, there needs to be as professors you get it, once you get the PhD, you're like, I understand why everybody can't do that, and that's okay.* **—CURRENT STUDENT**

This points out the importance of both appropriately screening applicants and ensuring that faculty advisors are equipped to provide the necessary support and guidance to students so they can meet degree milestones and be successful. Interviewees also noted that program curriculum requirements and teaching approaches need to be reviewed and modified to meet the contemporary needs of prospective students and create more inclusive learning environments for the diverse student body entering SFIS programs with varied academic and professional backgrounds. Interviewees repeatedly cited the ASU Charter and Mission as a core strength and value for both ASU and the School in terms of its contributions to diversifying the student body. Multiple interviewees shared specific stories about students who were from different life stages, professional and academic backgrounds, nations of origin, and other unique attributes. There is no "typical student" for ASU, and this was reflected in conversations with SFIS-affiliated faculty, staff, students, and alumni. Despite the challenges of marketing SFIS programs to such diverse audiences, recruiting diverse student cohorts creates rich classroom discussions and leads to unique research outcomes.

Many SFIS faculty, students, and alumni we interviewed urged reassessment of SFIS's academic programs in terms of their learning outcomes and related, potential career outcomes. In fact, this has already begun; at the time of our interviews, SFIS was undergoing an external review. This included "catalyst conversations" with internal and external stakeholders that were designed to determine how SFIS can meet its mission, what the future of SFIS should look like, and how it can achieve these goals. This review should illustrate ways SFIS can adapt its programming to better serve students and build a clearer identity within ASU's massive campus.

Summary

SFIS demonstrates how STEM-in-Society programs navigate growth in the face of both typical higher education trends and challenges that are unique to younger interdisciplinary programs. It also clearly shows how STEM-in-Society programs can be particularly vulnerable to the university context. ASU's priority on inclusive, accessible education places outsized pressures on SFIS

to grow its student enrollment even though its programs are relatively large compared to sister STEM-in-Society programs around the country. Holding STEM-in-Society programs to the same enrollment standards as long-standing disciplines also devalues the unique contributions of these programs.

The variety of unique degrees offered by SFIS demonstrates its emphasis on supporting interdisciplinary programs and providing an administrative home for degrees that might otherwise not be available to ASU students. Contemporary technosocial problems are inherently interdisciplinary, and STEM-in-Society programs like SFIS provide important opportunities for students who want to work in this space. However, these unique education offerings can be difficult to market to prospective undergraduate students due to the lack of alumni career data and competition with other, more well-established degree programs. These challenges are particularly acute for programs that aim to attract and serve first-generation college students who are paying particular attention to the cost of higher education and utility of a college degree in terms of job prospects and potential earnings.

Further, despite the support of ASU's president and the unique needs of its program, SFIS struggles to improve its prospective student outreach, marketing, student advising, and career services due to insufficient access to staff. Recent large-scale changes on ASU's main campus, namely the creation of the Global Futures Institute and College of Global Futures, may help address this need.

SFIS also reflects the challenges of providing interdisciplinary training for graduate students who require structured curricula in order to gain the necessary professional skills and identities required to navigate their education and careers. While STEM-in-Society programs are valuable in their unique, interdisciplinary approach, this same interdisciplinarity runs the risk of introducing students to a breadth of introductory concepts without the necessary structure or guidance needed to build a professional skill set and/or identity. Again, investing in proper marketing and providing positive, constructive mentorship and advising services for students will be key for these programs to support student success.

CASE STUDY

PROGRAM SNAPSHOT

Neuroscience and Public Policy Program, University of Wisconsin–Madison

HIGHLIGHTS

- University of Wisconsin–Madison's Neuroscience and Public Policy (N&PP) Program is an intensive dual degree program that requires students to apply for, and concurrently pursue, both a STEM doctorate (in neuroscience) and public affairs or law degree.
- N&PP students complete dual degree requirements, including completing coursework and research requirements, in the same timeline as their PhD-only peers.
- The required N&PP seminar, taken each semester during students' graduate school careers, examines the intersections of neuroscience and policy through related readings, guest speakers, and seminar discussions.
- N&PP Program alumni work in a range of science policy agencies and roles, and those who stay in neuroscience research tend to incorporate their policy training by designing socially relevant research questions or contributing to policy advising.

A Dual Degree Option for STEM Doctoral Students

The Neuroscience and Public Policy (N&PP) Program at the University of Wisconsin–Madison (UW–Madison) demonstrates how a dual STEM and non-STEM degree program prepares students to work at the intersection of neuroscience and policy. N&PP also illustrates how students' experiences are affected when their dual degree experience is administered by a STEM program.

N&PP enables UW–Madison students to simultaneously earn both a Neuroscience PhD and an additional policy or law degree of their choice. Options for the latter include a Master's of Public Affairs (MPA), Master's of International Public Affairs (MIPA), or a Juris Doctor (JD). Two core beliefs motivate N&PP: "First, that sound science and technology policy and law are essential for the well-being of societies." And second, that creating and implementing sound policies requires preparing future scientists in public policy (or law) so they can "participate in bringing science and society closer together."[98]

N&PP's rooting in the Neuroscience Training Program (NTP) contributes to a research culture that prioritizes the neuroscience side of students' learning experience, depending on their primary advisor's perspective and level of support for their dual degree obligations. NTP is an interdisciplinary program focused on preparing neuroscience students for research and teaching careers through "faculty trainers" who supervise doctoral students in their labs. While N&PP students are technically part of two degree programs within independent campus units (and N&PP maintains a faculty steering committee with representation from law, public affairs/policy, and multiple STEM fields[99]), each of N&PP's three faculty directors have been neuroscientists since the program was initiated in 2004. The N&PP Faculty Director leads the N&PP Steering Committee, advises students, and leads the N&PP Seminar.

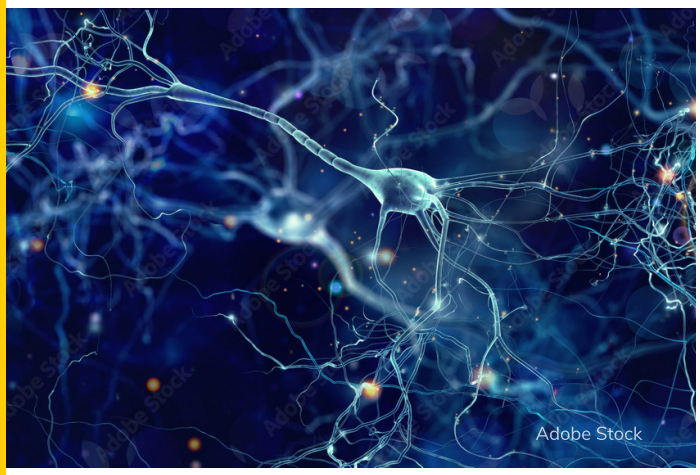
At present, there is no comparable program that offers N&PP's level of intensive graduate-level neuroscience training and public affairs education, and N&PP faculty want to improve its marketing to attract highly qualified students who can benefit from this unique learning experience. However, due to N&PP's specialized nature and highly competitive application process, the program recruits fewer than 5 students per year.[100] While the NTP does contribute some staff time to student recruitment and advising, including advertising the program at conferences (e.g., Society for Neuroscience), N&PP's enrollment numbers remain low.

For students who are accepted and choose to attend N&PP, having the structure to pursue their prior interest in the social aspects of neuroscience research is the primary draw.

> *For me, it was important to do scientific research that is grounded in society, to understand how my work can influence public policy and vice-versa. And so it was important for me to get educated in that respect, and that's why I chose this program.* **—N&PP ALUM OR STUDENT**

> *One of the benefits of being in a formally institutionalized program is that we don't have to take on public affairs learning as an extracurricular. Everything that we learn does receive credit and is very formal in that respect. And thankfully, I think our coursework is really enriching. We learn how to write policy briefs. We learn how to analyze policies. We get a peek into how public administration works and what implementation is in the policy world. [...] The policy component, I think, is the added part that makes this experience so rich.* - **NPP ALUM OR STUDENT**

To be accepted, prospective students must meet admissions requirements for both the NTP and the La Follette School of Public Affairs (or law school, as appropriate).[101] This includes demonstrating their interest in the N&PP Program and describing how they plan to integrate the two fields of study



in their careers in their application statements. They must also demonstrate their ability to take on a large course load. Previous experience in public policy is not required. Both the La Follette School (or law school) and the N&PP director review applicants' materials, but ultimately the NTP has the final say in whether applicants will be invited for an admissions interview based on their complete application materials. This admissions process is designed to identify students who will be successful in completing both degrees while still fulfilling their neuroscience research obligations. The majority pursue the dual Neuroscience PhD and MPA option.[102]

> *When they start the program, they're doing classes in neuroscience, but then they're also doing the concurrent classes for the MPA. And so, we do need students that have been able to demonstrate that they can manage a lot of classes. We also look for, in their statement, we're looking for what brings them to this topic. And we don't require that students have some kind of experience in public policy, because sometimes we find that students, you can tell that they're big picture thinkers. They're interested in the intersection of science and policy. They might have questions in a certain topic that have inspired them, but we don't necessarily require them to have demonstrated policy experience. What we really want to see is a spark and that they're interested and that they've thought about it.*
> **—FACULTY**

Accepted students receive an initial year of financial support through the National Institutes of Health (NIH)'s Predoctoral Training Program in the Neurosciences which funds fundamental research training at US-based universities. The primary objective of these awards is to "prepare individuals for careers in neuroscience that have a significant impact on the health-related research needs of the Nation."[103] After this initial funding, students are typically funded by neuroscience grants awarded to their assigned NTP advisor and lab, or they find and secure their own research grant or graduate fellowship award. Their additional degree home does not provide tuition or research assistant support.

Integrating Neuroscience and Public Affairs Training

N&PP is a highly demanding program. N&PP students must meet separate degree requirements while also gaining an integrated understanding of the intersections of neuroscience and policy. Faculty, students, and alumni all commented on the rigorous nature of the program, which is typically completed within the same

timeline as students who pursue a PhD alone. In addition to completing coursework for both degrees, students have to meet additional, N&PP-specific requirements.[104] This includes an N&PP Seminar, N&PP research paper, and an N&PP internship. Students must also build an advisory committee that includes faculty members from both the NTP and the School of Public Affairs.[105] To navigate these demands, students and alumni commented on the importance of high quality faculty mentorship, specifically mentioning the importance of the N&PP Program Director's role helping them balance sometimes competing obligations. Students also rely on the support of a peer network that includes both current N&PP students and alumni.

The required Neuroscience and Public Policy Seminar, which meets twice monthly, is the cornerstone of the program because it enables students to explore intersections of neuroscience and policy which they lack in their separate degree programs.[106] They must take it every semester. Topics include incarceration and brain health, policies surrounding sports injuries and concussions, and COVID education. The seminar also invites guest speakers who expose students to alternate career paths beyond academia.

> *We meet once a week, and the students who are enrolled in the program include both our neuroscience and public policy graduate students, but it's open to other graduate students on campus as well as undergraduates. As part of that seminar, we identify topics, speakers, and also some student choice topics, all at the intersection of neuroscience and public policy.* —**FACULTY**

Because it is open to all, the seminar also enriches the campus environment. Interested undergraduates, for example, can discover their interdisciplinary interests at this intersection. While they could be majoring in any subject, most come from neuroscience or engineering.

> *I'm also proud of our Neuroscience and Public Policy Seminar in the sense that I think we've provided a really engaging opportunity for students who are maybe not part of our program, but who are interested in the topics that we cover. So we have had, for example, undergraduate students who've joined the class and then have returned over multiple semesters because they found that the topics that we discussed were ones that they hadn't really encountered in other classes.* —**FACULTY**

> *Having those individuals come and then speak to our students is also really useful because it gives our students a better view of the landscape that they might not get from just their lab. If you're working in a lab under a scientist perhaps who's not engaged in policy, then that might be the only path that you see, right? You get your PhD, you get a postdoc, you become an academic researcher, and you get grants, and you study your research question. And I think through the seminar, they get to see role models who are doing other things that takes their expertise in science and then brings in policy and they're doing other interesting things, sometimes more impactful than perhaps what you would do just in one scientific lab. So that is also, I think, a real benefit of the seminar.* —**FACULTY**

After completing their first six semesters, N&PP students complete a "comprehensive research paper on a topic that bridges neuroscience and public policy." Students present the paper

to their thesis advisory committee and, if their paper and presentation are approved, fulfill half of their preliminary exam requirements for the PhD in Neuroscience through this process.[107] Some students opt to incorporate the paper into their dissertations in order to demonstrate their neuroscience policy knowledge and public affairs training to potential employers.

While interviewees noted the benefits of their N&PP training, they also reflected that students sometimes have to navigate tension stemming from NTP advisors not always fully understanding N&PP students' motivations to pursue two degrees or some NTP faculty's belief that students' neuroscience research commitments should always take precedence over their MPA degree requirements. The belief that STEM training is more valuable or important is a reoccuring theme across case studies and something that future scientists and engineers attempting to bridge academic disciplines must navigate through as they pursue STEM-in-Society training.

Career Paths for Neuroscience and Public Policy Graduates

The required N&PP internship gives students the chance to explore career options at the intersection of neuroscience and policy. Summer internships must be in an area of science and public policy, and typically students work within a state or federal government agency, advocacy organization, science funding agency, patient organization, or scientific professional organization.[108]

After graduating, some N&PP alumni choose to stay in academia, but maintain a professional interest in policy. Like STPP STEM students, N&PP students who stay in academia or research use what they've learned to design research questions that are more socially relevant or more likely to have positive impactful outcomes for general publics. It is more typical, however, for N&PP students to shift from research to science consulting or public affairs positions that integrate their dual-degree training and knowledge.

We have had students that have, for example, gone to work at the NIH, either as program officers or health policy analysts. One of our students is an emerging technology advisor at the United States Agency for International Development. Another is now a program and policy analyst at the Division of Juvenile Corrections. We have a couple of students that are currently in postdoc positions. Those are considered more along the academic route, but they've also been able to bring with them some of their training from policy and carry those interests forward. **—FACULTY**

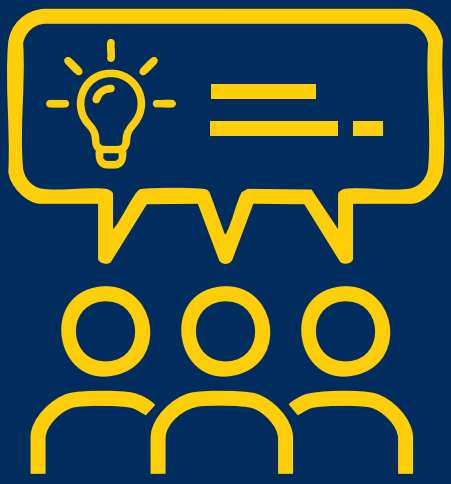
Much of what we do as scientists is influenced by what's going on around us, whether we are aware of it or not. [...] This program puts us in a position where we can gain a unique perspective. We can train on how federal and state entities operate to some extent. [...] We train about policymaking, process theories. We actually learn how to write policy reports, policy briefs. We learn how to analyze

> *policies. And that really gives us a different perspective on how decisions are made at a level that could impact scientists. And then, of course, with our rigorous scientific training, we already have that perspective. But I think this just makes us more like, give us a broader perspective.* **—N&PP ALUM OR STUDENT**

Due to the N&PP Program's small size, intensive requirements, and specialized nature, it has formed a small but tight-knit alumni community that extends peer-to-peer support to current students. This demonstrates the importance of built-in support structures for STEM-in-Society program students who are pursuing not only a unique academic experience but also are sharing the experience of unique career journeys that require mentorship and community perhaps more than other, more straightforward STEM career paths.

Summary

N&PP illustrates the niche role of STEM-in-Society programs designed for graduate students desiring both rigorous STEM and public policy/public affairs training. Alumni of this program spoke to the demanding nature of obtaining two graduate degrees, and completing N&PP requirements, in the same timeline as their PhD-only peers. Despite the challenges, however, graduates were largely appreciative of their experience and believe that their dual-purpose training opened professional doors for them. The specialized nature of N&PP, combined with highly competitive admissions requirements of UW–Madison's Neuroscience Training Program, significantly limits its audience. It also shows that students are often caught between their desire to complete dual-training and STEM faculty expectations that they will give preference to, or prioritize, their lab research over public policy coursework and training. Having a supportive alumni base, peer students, and a dedicated N&PP faculty director who advocates for, mentors, and supports students through these experiences is key to student success in such programs.



Recommendations

Our comprehensive analysis suggests that STEM-in-Society higher education programs around the country use a variety of creative methods to provide rigorous training for scholars, STEM professionals, policymakers, and advocates dedicated to responsible scientific research, technology, and evidence-based public policies. However, they tend to be underfunded, and ignored by university administrators and funders despite recent initiatives to cultivate interdisciplinarity and address the social and ethical challenges posed by emerging science and technology.

Below, we provide recommendations on how to strengthen and expand the national landscape of STEM-in-Society training programs. We focus our attention on three key audiences of decision makers: funders and other organizations interested in cultivating more responsible scientific research, technology, and evidence-based public policies; university administrators; and STEM-in-Society program administrators and leaders. We hope that this report and recommendations enable deeper understanding and recognition of the ecosystem, provide guidance on the challenges STEM-in-Society programs face and how they might be addressed, and enable mutual learning to strengthen these programs and ultimately, train the next generations of leaders to address complex science and technology problems.

Recommendations for National Organizations Interested in Supporting the STEM-in-Society Ecosystem

Develop the ecosystem

- Create long-term funding opportunities that strengthen existing STEM-in-Society programs—particularly those based in the humanities and social sciences—rather than simply launching new ones. These programs provide the intellectual engine for critical understanding of how science, technology, and related public policies both shape and are shaped by societies.
- Recognize and support institution-specific goals. There is no "one size fits all" approach to STEM-in-Society program design (e.g., a small, private liberal arts college will have different needs than a large, public minority-serving institution).
- Convene regular meetings across STEM-in-Society programs to foster mutual learning and potential collaboration.
- Encourage accreditation organizations to require, or at least recognize, the importance of STEM-in-Society training.

Expand learning opportunities

- Create more STEM-in-Society fellowship programs for professionals who want to translate their technical expertise and professional experience into a STEM-in-Society career (e.g., NSF postdoctoral fellowships).
- Enable the design, delivery, and evaluation of short-term STEM-in-Society bootcamps or professional workshops for STEM-trained students, postdoctoral researchers, and faculty.
- Collaborate with non-profit organizations, government agencies, and professional associations to support or create STEM-in-Society learning opportunities that operate outside of higher education (e.g., Civic Science Fellows, AAAS science and technology policy fellowships).

Foster leadership

- Provide strategic planning assistance to help STEM-in-Society programs identify opportunities to increase their education and public engagement impacts.
- Invest in mentorship and professional development programs that foster leadership development for STEM-in-Society faculty, postdoctoral researchers, and staff.
- Create a leadership pipeline to increase STEM-in-Society programs' long-term stability. This might include creating funded opportunities for faculty to shadow a STEM-in-Society program leader, supporting executive coaching for program leaders, and matching early career STEM-in-Society faculty and staff with more experienced mentors.

Recommendations for University Administrators

Build institutional resources

- Train career services offices to serve students interested in STEM-in-Society programs, and encourage them to develop internship partnerships with STEM-in-Society-focused organizations (e.g., government offices and civil society groups focused on the intersection of STEM and society).
- Foster connections between STEM-in-Society programs and efforts to cultivate research impact (including offices dedicated to supporting PhDs seeking non-academic careers).
- Remove barriers to the creation and marketing of STEM-in-Society programs across campus.
- Remove barriers for students enrolling in STEM-in-Society program courses (e.g., making course approvals and cross-listing courses easier).

- Build financial support for STEM-in-Social programs by ensuring that revenues generated benefit these programs.
- Reconsider tenure and promotion processes to ensure that candidates are not disadvantaged by doing inherently interdisciplinary work.
- Encourage dual faculty appointments between STEM and the humanities and social sciences, but require units to provide plans for tenuring and promoting these unique candidates.
- Encourage accreditation organizations to require, or at least recognize, the importance of STEM-in-Society training.

Facilitate interdisciplinary collaboration

- Encourage STEM programs to require students to take STEM-in-Society courses for their humanities and social science requirements, and take steps to remove relevant barriers.
- Create incentive programs to foster interdisciplinary research across STEM, the humanities, and the social sciences. But this funding should also include support for managing the challenges that interdisciplinarity creates.
- Create public-facing (e.g., on university websites) directories of all STEM-in-Society programs associated with the institutions and their approach and activities.
- Strongly encourage STEM units developing STEM-in-Society courses, programs, or research activities, to collaborate with those located in the humanities and social sciences to ensure that the training provided is rigorous and that they are not co-opting programming from less powerful entities on campus.
- Support campus events showcasing the expertise of STEM-in-Society programs so that those newly interested in these questions become aware of centers of expertise.
- Integrate STEM-in-Society programs into campus efforts focused on responsible research and innovation (e.g., IRBs, research compliance) to improve research while supporting campus STEM-in-Society programs.

Create consistent funding streams

- Provide adequate funding for STEM-in-Society programs, including faculty and staff support, marketing and communications, and student and career services, that enables maintenance but also facilitates adaptability as new science and technology issues emerge.
- Train staff at development offices so that they understand STEM-in-Society programs and can assist with fundraising.
- Provide dedicated fellowships or scholarships for students who seek to enhance their STEM degrees with STEM-in-Society training.

Recommendations for STEM-in-Society Program Leaders

Broaden student recruitment

- To increase enrollment, streamline degree requirements and offer varied formats for courses, including online, weekend, and internship options.
- Develop marketing materials to help students and, as relevant, their families, understand the benefits of participating in a STEM-in-Society program, starting from before they enroll at the university. Consider marketing programs by emphasizing how the world's most difficult challenges require not just interdisciplinarity, but STEM-in-Society knowledge.
- Consider developing a suite of non-traditional educational programs (e.g., continuing professional education, bootcamps, online courses, postdoctoral training fellowships) for STEM and other professionals who want to acquire STEM-in-Society knowledge and skills that will help them advance or pivot in their careers.

Enhance career support

- Provide career services for students interested in pursuing both academic and non-academic careers, with an eye towards the long-term.
- Help students build their professional identities so they can be more confident and successful on the job market.
- Make program learning outcomes, professional development opportunities, and associated benefits (and trade-offs) transparent for prospective students.
- Track alumni, and leverage alumni networks to broaden students' understanding of career pathways.

Leverage data

- Set strategic goals for learning objectives and alumni outcomes, and develop processes for tracking and evaluating outcomes. This may include benchmarking against peer programs.
- Work with other STEM-in-Society programs through conference convenings and other means to share best practices, challenges, and potential inter-university collaborations.
- Take advantage of opportunities to connect with the leaders of STEM programs and explain STEM-in-Society and its value, particularly for ensuring diversity, equity, inclusion, and justice in STEM.

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Endnotes

1. "What is PIT," New America, accessed December 3, 2024, https://pitcases.org/wp-content/uploads/2023/10/002_What-is-PIT_.pdf.

2. The "program snapshot" is a briefer profile of a STEM-in-Society program. Compared to the other cases, there were fewer interviewees available; we were not able to get a thorough history; and the program itself is very small. However there were still important lessons to be learned, and we did not want to exclude it altogether.

3. Science, Technology, Engineering, and Mathematics

4. Lee Rainie and Janna Anderson, "The Future of Jobs and Jobs Training," Pew Research Center, May, 2017, https://www.pewresearch.org/internet/2017/05/03/the-future-of-jobs-and-jobs-training/; Jessica Wyndham, Robert Albro, Joshua Ettinger, Kathryn Smith, Maya Sabatello, and Mark Frankel, March 2015, "Social Responsibilities: A Preliminary Inquiry into the Perspectives of Scientists, Engineers and Health Professionals" (Report prepared under the auspices of the AAAS Science and Human Rights Coalition and AAAS Scientific Responsibility, Human Rights and Law Program), https://doi.org/10.1126/srhrl.aaa9798; Helen Pearson, "Science could solve some of the world's biggest problems. Why aren't governments using it?," Nature 636, 26-30 (2024), doi: https://doi.org/10.1038/d41586-024-03906-0.

5. Helen Pearson, "Science could solve some of the world's biggest problems."

6. National Science Foundation, *STEM Education for the Future: A Visioning Report*, (National Science Foundation Subcommittee of the Advisory Committee of the Education and Human Resources Directorate, May 2020) https://nsf-gov-resources.nsf.gov/files/STEM-Education-2020-Visioning-Report.pdf?VersionId=tUx9eN9NEXtNHIghTfPOA7L81c28KMs7.

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9. Science and Justice Research Center, "Experiments in Collaboration," 2.

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11. "Science and Society," The Kavli Foundation, accessed December 3, 2024, https://www.kavlifoundation.org/science-and-society.

12. "Celebrating the 2nd anniversary of the 'CHIPS and Science Act of 2022' — and what it means for America's new innovation frontier," National Science Foundation, updated August 13, 2024, accessed February 19, 2025, https://new.nsf.gov/tip/updates/celebrating-2nd-anniversary-chips-science-act-2022.

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19. "Office of Science and Technology Policy," The Obama White House, accessed December 3, 2024, https://obamawhitehouse.archives.gov/administration/eop/ostp/about.

20. "Public Interest Technology," Ford Foundation, accessed December 3, 20224, https://www.fordfoundation.org/news-and-stories/big-ideas/public-interest-technology/.

21. "What is PIT," New America, accessed December 3, 2024, https://pitcases.org/wp-content/uploads/2023/10/002_What-is-PIT_.pdf.

22. Jennifer J. García, Cheryl Grills, Sandra Villanueva, Karren A. Lane, Curtiss Takada-Rooks, and Christopher D. Hill. "Analyzing the landscape: community organizing and health equity," *Journal of Participatory Research Methods* 1, no. 1 (2020), https://doi.org/10.35844/001c.13196.

23. Jennifer J. García, et al., "Analyzing the landscape"; Christine Sherry, "Fast forward to greater impact: The power of field scans," National Center for Family Philanthropy, https://www.ncfp.org/knowledge/fast-forward-to-greater-impact-the-power-of-field-scans/.

24. The "program snapshot" is a briefer profile of a STEM-in-Society program. Compared to the other cases, there were fewer interviewees available; we were not able to get a thorough history; and the program itself is very small. However, there were still important lessons to be learned, and we did not want to exclude it altogether.

25. We included 224 websites representing 246 STEM-in-Society programs in our analysis. The number of websites is smaller than the number of programs because some degree programs hosted by the same institute share the same website.

26. University staff or faculty members representing 82 degree programs distributed across 40 universities responded to the survey.

27. STEM-in-Society programs include: degrees (including dual degrees, dual majors and degree concentrations), certificates and minors. These programs were evenly distributed between private and public institutions.

28. Only 5 percent of schools that host STEM-in-Society programs were small liberal arts colleges.

29. "Cybersecurity, Technology and Policy," Jack D. Gordon Institute for Public Policy, accessed February 18, 2025, https://gordoninstitute.fiu.edu/professional-education/cybersecurity-technology-and-policy/.

30. "Coursework," Science, Technology, and Public Policy, accessed February 19, 2025, https://stpp.fordschool.umich.edu/graduate-certificate/coursework.

31. "On-campus vs. Online," Arizona State University, accessed February 19, 2025 https://sfis.asu.edu/degree-programs/masters-programs/gtd-2/on-campus-vs-online/.

32. Stephanie Marken and Drew Curtis, "Four in 10 College Students Have Had Internship Experience," Gallup, updated August 16, 2023, https://www.gallup.com/education/509468/four-college-students-internship-experience.aspx; Nina Agrawal, "Internships matter more than ever — but not everyone can get one," The Hechinger Report, updated March 30, 2024, https://hechingerreport.org/internships-matter-more-than-ever-but-not-everyone-can-get-one/; Melissa Ezarik, "A Need to Succeed: What Students Want and Get From Internships," Inside Higher Ed, updated September 22, 2022, https://www.insidehighered.com/news/2022/09/23/students-internship-experiences-how-they-want-colleges-help.

33. Appendix C lists the 15 categories of experiential learning opportunities we identified. Each of these is offered by two or more programs. We also provide examples for each category, state the number of unique undergraduate and graduate programs that mentioned each category, and include illustrative quotes for each category.

34. "Science, Technology, Ethics and Policy (STEP) Undergraduate Minor," University of Maryland School of Public Policy, accessed February 19, 2025, https://spp.umd.edu/science-technology-ethics-and-policy-step-minor.

35. "Law, Policy, and Engineering (LPE)," Penn State, accessed February 19, 2025, https://bulletins.psu.edu/university-course-descriptions/graduate/lpe/.

36. Examples of course titles with a DEIJ emphasis included: "Race, Genomics and Society," "Feminist Theory and STS," "Human Rights and World Politics," and "Social Justice and Medicine".

37. Human rights and disability were each mentioned by only two programs.

38. "Program Features," Loyola University, accessed February 19 2025, https://www.luc.edu/stritch/bioethics/graduateeducation/programfeatures/.

39. "Ethics Meets AI at Nazareth," Nazareth University, accessed February 19, 2025, https://www2.naz.edu/ethics-meets-ai-nazareth/.

40. "Gender, Science, and Technology Minor," Virginia Tech College of Liberal Arts and Human Sciences, accessed February 19 2025, https://liberalarts.vt.edu/academics/majors-and-minors/gender-science-and-technology-minor.html.

41. "Course Threads, Sciences and Society," University of California, Berkeley, accessed February 19, 2025, https://coursethreads.berkeley.edu/threads/sciences-society.

42. "Technology, Artificial Intelligence & Society Bachelor of Arts," Nazareth University, accessed February 19, 2025, https://www2.naz.edu/academics/technology-artificial-intelligence-society-major/.

43. "History of Health Sciences," University of California San Francisco, accessed February 28, 2025, https://humsci.ucsf.edu/history-health-sciences.

44. "Science & Justice Training Program," Science & Justice Research Center, accessed February 19, 2025, https://scijust.ucsc.edu/pedagogy/sjtp/.

45. "Master of Science in Bioethics," The University of Texas Rio Grande Valley, accessed February 19, 2025, https://www.utrgv.edu/programs/ms-bioethics.htm.

46. "BIET 7300 Capstone Master's Project," The University of Texas Rio Grande Valley, accessed February 19, 2025, https://utrgv.smartcatalogiq.com/en/2024-2025/graduate-catalog/courses/biet-bioethics/7000/biet-7300/.

47. "Graduate Certificate in Science, Technology and Society," Georgia Tech Public Policy Program, accessed February 19, 2025, https://spp.gatech.edu/graduate/certificates/sts.

48. "Ethics, Public Policy, Science and Technology Undergraduate Minor," California Polytechnic State University, accessed February 19, 2025, https://sts.calpoly.edu/students/ethics-public-policy-science-technology-eppst-minor.

49. "Science, Technology, and Innovation for Global Development Graduate Certificate," Worcester Polytechnic Institute, accessed February 19, 2025, https://www.wpi.edu/academics/study/science-technology-innovation-global-development-certificate.

50. "Global Technology and Development MS Program," Arizona State University, accessed February 19, 2025, https://asuonline.asu.edu/online-degree-programs/graduate/master-science-global-technology-development/.

51. "History of Health Sciences Graduate Program," University of California, San Francisco, accessed February 19, 2025, https://humsci.ucsf.edu/history-health-sciences.

52. Due to the Neuroscience and Public Policy Program's smaller size and the limited number of interviewees available, we are providing a program snapshot that provides an introductory background on this program's vision, student experiences, and alumni outcomes.

53. Note that each case study measures student enrollment differently. Within each case study, the enrollment numbers provided for the 2023-2024 school year include "active" students as defined by each respective case study. For example, the total number of active students in Virginia Tech's STS MS and STS PhD programs includes part-time students who do not necessarily enroll in courses every term.

54. "Department of Engineering and Public Policy," Carnegie Mellon University, accessed February 19, 2025, https://www.cmu.edu/epp/.

55. "Institutional Research and Analysis, Office of Institutional Effectiveness and Planning," Carnegie Mellon University, accessed February 19, 2025, https://www.cmu.edu/ira/Enrollment/index.html.

56. A joint effort between the School of Engineering and the predecessor of the current Heinz School of Public Policy resulted in EPP becoming a fully formed Department in the late 1970s. In 1972, economist and former Dean of the Business School Dick Cyert became University President. Instead of investing in narrowly defined disciplines, Cyert devoted resources to supporting more interdisciplinary research endeavors. This coincided with the creation and expansion of EPP within the College of Engineering.

57. Interviewees typically referenced MIT's Technology and Public Policy program as the most comparable example but noted that MIT no longer offers a doctoral degree.

58. "Course Requirements," Engineering and Public Policy College of Engineering, accessed February 19, 2025, https://www.cmu.edu/epp/prospective/doctoral-studies/course-requirements/index.html.

59. Office of the Executive Vice President and Provost, "New Degree Programs," Office of the Executive Vice President and Provost, Virginia Tech, accessed December 31, 2024, https://www.provost.vt.edu/executive-vice-provost/schev-compliance/new-degree-programs.html.

60. Currently the College of Liberal Arts and Human Sciences.

61. "Pathways General Education: Structure, Concepts, and Learning Outcomes," Virginia Tech, accessed December 5, 2024, https://www.pathways.prov.vt.edu/structure-concepts-learning-outcomes.html.

62. This course introduces students to the evolution and contemporary practice of engineering in different international contexts.

63. "IUSE/Professional Formation of Engineers: Revolutionizing Engineering Departments (IUSE/PFE: RED)," U.S. National Science Foundation, accessed December 5, 2024, https://new.nsf.gov/funding/opportunities/iusepfe-red-iuseprofessional-formation-engineers-revolutionizing.

64. "Innovation Campus," Virginia Tech, accessed February 20, 2025, https://www.vt.edu/innovationcampus/index.html.

65. "Tech for Humanity," Office of the Executive Vice President and Provost, accessed December 5, 2024, https://www.provost.vt.edu/destination_areas/tech-for-humanity.html.

66. "Our Mission," Science, Technology, and Public Policy," accessed January 6, 2025, https://stpp.fordschool.umich.edu/.

67. Data provided by STPP staff.

68. Data provided by STPP staff.

69. "PUBPOL 650: Introduction to Science and Technology Policy Analysis," Ford School, accessed February 20, 2025, https://fordschool.umich.edu/course/winter/2015/pubpol-650-introduction-science-and-technology-policy-analysis.

70. "Coursework," Science, Technology, and Public Policy, accessed February 19, 2025, https://stpp.fordschool.umich.edu/graduate-certificate/coursework; Approved STPP Certificate electives range from Business Policy; Space Policy; Biotechnology and Healthcare Policy; Information/Communication Technology Policy; Energy and Environmental Policy; Architecture, Urban Planning, and Transportation Policy; General Science and Technology Policy.

71. The program's size has varied over the years, with enrollment reaching 62 students during the 2023-2024 school year. This includes STPP Certificate students who were actively taking certificate courses during the Winter 2024 term. Data provided by STPP staff.

72. "Justice and Equity in Technology Policy," Michigan Online, accessed February 20, 2025, https://online.umich.edu/courses/justice-and-equity-in-technology-policy/.

73. "STPP to establish Michigan science and technology fellowship," Ford School, updated November 14, 2024, https://fordschool.umich.edu/news/2024/stpp-establish-michigan-science-and-technology-fellowship.

74. "History of SJRC," Science and Justice Research Center, accessed February 20, 2025, "https://scijust.ucsc.edu/about-sjrc/science-and-justice-at-ucsc/.

75. "Research Institutes, Centers, and Reserve System," "UC Santa Cruz," accessed January 8, 2024, https://science.ucsc.edu/research/institutes/.

76. "Founded in 1972, Oakes College is a multicultural community committed to equality and freedom from oppression and to providing the highest quality education to students from diverse backgrounds." https://oakes.ucsc.edu/academics/index.html.

77. Science and Justice Research Center (Collaborations Group), "Experiments in Collaboration: Interdisciplinary Graduate Education in Science and Justice," PLoS Biology 11 no. 7 (2013): 2, https://doi.org/10.1371/journal.pbio.1001619.

78. Science and Justice Research Center, "Science and Justice Training Program," accessed December 10, 2024, https://scijust.ucsc.edu/pedagogy/sjtp/.

79. SJRC, "Experiments in Collaboration: Interdisciplinary Graduate Education in Science and Justice," 1.

80. SJRC, 2.

81. "Kriti Sharma," Critical Race and Ethnic Studies, accessed January 8, 2025, https://humanities.ucsc.edu/academics/faculty/index.php?uid=ksharm35.

82. Science, technology, engineering, mathematics, and medicine

83. Diversity, equity, and inclusion

84. Ethical, legal, and social implications of research

85. "Welcome to LEED of STEMM," Leadership in the Equitable and Ethical Design (LEED) of STEMM Research, accessed February 20, 2025, https://leed.ucsc.edu/.

86. Science and Justice Research Center publications available at https://scijust.ucsc.edu/research/reports-and-publications/.

87. Although CSPO no longer confers degrees, the Consortium still provides professional development for government agency staff, and CSPO faculty and staff continue to teach online SFIS courses.

88. "How we work," Julie Ann Wrigley Global Futures Laboratory®, accessed February 20, 2025, https://globalfutures.asu.edu/.

89. The Julie Ann Wrigley Global Futures Laboratory® also hosts an Office of Research Services that provides research support services in the form of research development and strategy assistance, research analytics and communications, and other services.90

90. "ASU Facts and Figures" Arizona State University, accessed December 22, 2023, https://www.asu.edu/about/facts-and-figures.

91. The PhD program was largely named to align with the language that was, at the time, being used by the NSF. Funded by the National Science Foundation, CNS was an integrated piece of CSPO that drove its research agenda after its integration into ASU.

92. CSPO acquired this program from ASU's Polytechnic Campus.

93. This also demonstrates how STEM-in-Society programs often make university service contributions through teaching undergraduate electives and general education requirements to non-majors.

94. The GTD and PIT MS degrees are both offered in this accelerated format that allows students to share 12 hours between their undergraduate and graduate degree programs which makes it possible for them to complete both degrees in 138 credits hours (instead of the typical 150 hours).

95. Graduate student career advising will continue to be the responsibility of SFIS faculty and staff.

96. The two required courses, HSD 601: Human Dimensions of Science and Technology and HSD 602: Science, Power and Politics, introduce students to literature relevant to the "human and social dimensions of science and technology" and introductory HSD research methods. To fulfill additional coursework hours, PhD students select two major fields and one minor field and take specialized elective courses, engage in independent reading, or participate in research projects.

97. "Human and Social Dimensions of Science and Technology, PhD," College of Global Futures School for the Future of Innovation in Society, accessed February 28, 2025, https://sfis.asu.edu/degree-programs/phd-programs/hsd

98. "Neuroscience and Public Policy Program," University of Wisconsin–Madison, accessed December 11, 2024, https://npp.wisc.edu/.

99. "Neuroscience Training Program," accessed December 11, 2024, https://ntp.neuroscience.wisc.edu/.

100. The NTP alone receives "More than 175 applications for admission to the Program are received each year, and 10 students, on average, matriculate." Source: Neuroscience Training Program, "Admissions," accessed December 11, 2024, https://ntp.neuroscience.wisc.edu/admissions/. N&PP had only 2 current students during the 2023-2024 academic school year.

101. "Admissions requirements," La Follette School of Public Affairs, accessed December 11, 2024, https://lafollette.wisc.edu/admissions/graduate-admissions-requirements/.

102. For this reason, this program snapshot focuses on the PhD/MPA dual degree option.

103. "Institutional Training Grants," National Institutes of Health, accessed December 11, 2024, https://researchtraining.nih.gov/programs/training-grants/T32-a.

104. Required courses for the Neuroscience PhD include: Cellular and Molecular Neuroscience, Systems Neuroscience, Professional Development, and a Neuroscience Seminar and a Research and Thesis course which are both taken each semester. PhD students must also fulfill an ethics requirement by taking either 2 ethics seminars or an approved ethics subgroup or course. Required courses for the MPA include: The Policymaking Process, Quantitative Tools for Public Policy Analysis, Microeconomic Policy Analysis, Introduction to Policy Analysis, Introduction to Public Management, and Workshop in Program Evaluation and Public Policy Analysis. In addition, MPA students must take 21 elective credits and complete a Public Policy Internship. Four N&PP seminar credits can be used to fulfill MPA elective requirements.

105. "M.P.A./Ph.D. Program Requirements," Neuroscience and Public Policy Program," accessed February 28, 2025, https://npp.wisc.edu/m-p-a-ph-d-program-requirements/.

106. "N&PP Seminar," Neuroscience and Public Policy Program, accessed February 28, 2025, https://npp.wisc.edu/current-seminar-schedule/.

107. "M.P.A./Ph.D. Program Requirements," Neuroscience and Public Policy Program," accessed February 28, 2025, https://npp.wisc.edu/m-p-a-ph-d-program-requirements/.

108. "M.P.A./Ph.D. Program Requirements," Neuroscience and Public Policy Program," accessed February 28, 2025, https://npp.wisc.edu/m-p-a-ph-d-program-requirements/.

APPENDIX A

Research Design & Data Analyses

Identifying STEM-in-Society Programs

One of the challenges of identifying STEM-in-Society programs is that they are administered by an array of campus units—including departments, schools, and research centers—and have a variety of degree titles. For these reasons, we used multiple means to identify as many current STEM-in-Society programs as possible. We relied on publicly available program lists and supplemented this with internet searches using key terms such as "science policy,", "technology policy,", "science and technology policy,", "science ethics,", "bioethics." We also followed leads provided by STEM-in-Society program leaders during case study interviews. In total, we collected and analyzed textual data from 224 STEM-in-Society program websites between May–July 2023.

Categorizing STEM-in-Society Programs

We assigned each individual degree, minor, or certificate program to one of four categories based on its curriculum and learning objectives: science and technology studies (STS), ethics (ETH), public interest technology (PIT), or science and technology policy (STP). STS programs included those titled "Science, Technology and Society," "Science and Technology Studies," "History and Philosophy of Science," "History of Science, Medicine and Technology," and "Medical Humanities." Ethics programs primarily consisted of bioethics programs titled "Bioethics," or "Bioethics and Health Policy," but we also included "Technology Ethics" programs in the ethics category. PIT programs were typically titled "Public interest technology," but also included programs like "Responsible Innovation in Science, Engineering and Society" and "Science and Engineering in the Public Interest."

Within STP programs, we further distinguished between general STP; engineering policy; and programs that included general science and technology policy (STP), engineering policy, and specialized STP programs. General STP programs included those titled "Technology and Policy"; "Science and Technology Policy"; and "Science, Technology and International Affairs." Engineering policy programs emphasize the intersections of technical engineering problems with societal issues and policy. Specialized STP programs emphasize a specific technology or science issue area; examples include "Cybersecurity Policy"; "Nuclear Science, Technology, and Policy"; "Vaccine Science and Policy"; and "Neuroscience and Public Policy."

We also categorized each program by its host university type (public or private, research or teaching focus); degree title; degree level (undergraduate, graduate, or continuing professional education); and degree type (certificate, minor, major).

Website Data Analysis

We used descriptive statistics, aided by Microsoft Excel and Stata, to organize and describe these program characteristics at the landscape level and draw comparisons across different program categories. In addition, we used qualitative textual analysis to assess how they present their education programs and describe student learning experiences and professional outcomes. The four emergent themes we focused on were: experiential learning requirements or opportunities; program flexibility; diversity, equity, inclusion, and justice (DEIJ); and alumni career outcomes. For each of these topics, we used a two-stage coding process that included an initial coding phase to identify higher-level emerging themes and a second, more detailed coding phase to identify and summarize additional descriptive information of interest within each theme. All qualitative data coding was conducted in NVivo.

Program Survey

Our survey of STEM-in-Society programs was designed to collect information that was not consistently available on program websites. The survey questionnaire included a combination of closed-ended and open, short-answer response questions about an individual program's target audience, admissions requirements, history (year founded), funding sources, and size (faculty size and student enrollment). The survey was distributed to 231 STEM-in-Society programs, and we received responses from 82 degree programs (34% overall response rate) distributed across 40 universities. Because not every program responded to each question, response rates varied slightly by question. Program contacts were identified from contact information publicly available on program websites. Contacts included a mix of faculty and staff with titles such as program director, department chair, and program manager. General program contact emails were used wherever an individual program administrator or leadership figure could not be identified using the program website. Survey responses were summarized and analyzed using descriptive statistics and qualitative analysis in Microsoft Excel and Stata.

Case Study Interviews

We conducted 79 semi-structured interviews with a mix of program leaders, faculty, staff, students, and alumni affiliated with each case study. Interviewing individuals with different program experiences and perspectives allowed us to identify unique programmatic assets, challenges, and opportunities that might not have been identified if only one perspective was heard. Program leaders, and founders in particular, hold first-hand historical knowledge that illuminates common challenges of designing, implementing, and sustaining STEM-in-Society programs. Individual faculty members can speak to how learning objectives are achieved through their teaching efforts, research mentorship, and student advising. We also anticipated that program staff, in addition to interacting with students as advisors and supporting students from an administrative standpoint, would be able to provide program data including student enrollment and student

employment outcomes that they are tasked with tracking over time. Interviewing students was important in order to hear their firsthand experiences and learn what attracted them to their chosen STEM-in-Society program. And finally, we interviewed program alumni to understand how participating in a STEM-in-Society program impacted their job preferences and professional careers in both the short and long term. We interviewed case study participants over Zoom or in person during on-site visits. To understand the experiences of each of these distinct groups, we designed and used unique interview protocols for each group. We coded interview transcriptions using a directed thematic coding approach.

APPENDIX B

Study Limitations & Next Steps for Understanding the Field

It's clear that STEM-in-Society programs have long-term institutional and cultural impacts that extend beyond individual learning outcomes. Their faculty, students, alumni, and publications are helping to transform STEM fields and are also providing crucial expertise on science and technology in the public interest to policymakers, advocacy organizations, and citizens. As illustrated by our analysis, however, there is still much to learn about these programs, including how these programs support student professional development. STEM experts access responsible research and ethics training outside of STEM-in-Society programs, and we know little about the benefits and potential shortcomings of these non-credentialed options.

Additional areas for future research include exploring how applied learning experiences including internships and fellowships impact STEM-in-Society students' and graduates' professional choices and career options. This should include evaluating training options hosted by non-academic institutions such as professional associations, government agencies, and non-profit organizations. While our analysis did not include such programs, they were often mentioned as important to providing a bridge between higher education and the professional sector that helps students understand the real-world applicability of their STEM-in-Society training, hone their skills in a real-world setting, and improve their understanding of career options. Such programs are in limited supply, and evaluating how they affect employability and other related outcomes—and sharing these findings with a broader network of STEM-in-Society programs—would help inform what higher education programs are missing.

Our study was also limited by the interviewees we had access to within each case study. While we interviewed a combination of current students, alumni, staff, and faculty affiliated with each respective program, we did not interview higher education administrators within each case study institution. We also did not interview individuals who represent funding organizations that financially support STEM-in-Society programs. Interviewing these other key groups would be an appropriate next step for continuing this work and understanding the fuller picture of STEM-in-Society programs within the United States.

BROADENING HORIZONS

How STEM-in-Society Programs
Train Socially Responsible Scientists,
Engineers, and Policy Leaders

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