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Pathways of influence: understanding the impact of philosophy of science in scientific domains

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Abstract

Philosophy of science has the potential to enhance scientific practice, science policy, and science education; moreover, recent research indicates that many philosophers of science think we ought to increase the broader impacts of our work. Yet, there is little to no empirical data on *how* we are supposed to have an impact. To address this problem, our research team interviewed 35 philosophers of science regarding the impact of their work in science-related domains. We found that face-to-face engagement with scientists and other stakeholders was one of the most—if not the most—effective pathways to impact. Yet, working with non-philosophers and disseminating research outside philosophical venues is not what philosophers are typically trained or incentivized to do. Thus, there is a troublesome tension between the activities that are likely to lead to broader uptake of one's work and those that are traditionally encouraged and rewarded in philosophy (and which are therefore the most consequential for careers in philosophy). We suggest several ways that philosophers of science, either as individuals or as a community, can navigate these tensions.

Keywords Engaged philosophy of science · Impact · Productive interactions · Collaboration · Interdisciplinarity · Qualitative research · Interviews

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1 Introduction

The world is facing increasingly complex social and environmental problems in need of urgent solutions, such as climate change, systemic racism, and a rise in infectious diseases. Addressing these so-called "wicked problems" requires the perspectives of those with ethical and epistemic expertise in science and technology. Many philosophers of science have exactly this sort of expertise. Indeed, philosophers of science are particularly skilled at analyzing scientific concepts, methods, and inferences; identifying and interrogating underlying assumptions in scientific reasoning; examining the uses and misuses of scientific knowledge; and cultivating trust between scientists and lay communities (Grasswick 2010; Kourany 2010; Whyte and Crease 2010). Thus, scientific research can be more objective, more useful, and more responsible when philosophers are involved in analyzing the knowledge it produces and how that knowledge is used (Fisher and Mahajan 2006; Shrader-Frechette 2007; Douglas 2009).

While much of the work done by philosophers of science has the potential to enhance scientific practice, science policy, science education, and even public understanding of science, it is unclear to what extent our work is actually having an impact. There is growing concern about this state of affairs. Some have gone as far as to pronounce that philosophy, as a discipline, "has failed in terms of having an extra-disciplinary impact" (Briggle et al. 2015). Several philosophers of science have argued that we ought to take more engaged approaches—by making philosophical work accessible to broader audiences; disseminating it directly to scientists, policymakers, and others; and collaborating with scientists and non-academic stakeholders (Fehr and Plaisance 2010; Cartieri and Potochnik 2014; Dotson 2015; Frodeman and Briggle 2016; Plaisance 2020). Scientists themselves have highlighted the need for attention to philosophical issues in their work and have called for more collaboration between philosophers and scientists (Kostarelos 2013; Horgan 2014). Moreover, these views are not in the minority: in a recent survey of philosophers of science, over half of respondents said they think philosophy of science has an *obligation* to ensure it has an impact on science and on society more generally (Plaisance et al. 2019).

Certainly, there are examples of philosophical work that has successfully crossed disciplinary boundaries and positively influenced science and society, several of which have even been captured and discussed in recent philosophical literature (Plaisance and Fehr 2010; Tuana 2010; Brister and Frodeman 2020; Plaisance and Elliott 2021). What has yet to be systematically examined, however, is which pathways are most likely to be effective when it comes to the broader uptake of our work. In other words, the *need* for increasing our impact in science-related domains is well established, but little work has been done to determine *how* philosophers of science can get their work into the hands of those who can use it. At the 2014 Calgary Summit of Philosophy of Science, for instance, several prominent philosophers of science lamented the lack of influence of philosophical work in scientific domains. Yet, when it came to discussions as to how philosophers might remedy this situation, the only specific advice was to "publish

in science journals" and "collaborate with scientists." Unfortunately, this advice overlooks the tacit knowledge needed to publish in science journals and productively collaborate with scientists (Collins and Evans 2007; Plaisance 2020), and it ignores institutional and disciplinary barriers to engaged work (Fehr and Plaisance 2010; Plaisance et al. 2019). While some have begun to share strategies they have used to acquire the knowledge and skills for successful engagement, most of these discussions take place in informal venues like conferences and workshops, rather than in peer reviewed manuscripts. Briggle, Frodeman, and Barr encountered this problem first-hand when they analyzed applied philosophy journals to see if they could "identify 'best practices' for getting philosophic insights into the hands of nonphilosophers" (Briggle and Frodeman 2016, p. 34). The authors concluded, "we find essentially no accounts of how a philosopher is supposed to ensure that these insights have an impact" (Briggle et al. 2015).

Our project addresses this gap in our collective knowledge by providing empirical data about the broader impacts of philosophy of science. We employed a mixed-methods approach, surveying philosophers of science about their attitudes, experiences, and values regarding engaged work (Plaisance et al. 2019), and conducting in-depth interviews with philosophers of science to understand the particular contexts and conditions associated with high-impact work. In this paper, we report the findings from our interviews with philosophers of science, specifically regarding the types of impacts they've had, the pathways that led to broader uptake of their work, and how their efforts have influenced a variety of communities, including scientists, engineers, policymakers, and students.[1] While our survey data enabled us to develop a statistical portrait of philosophy of science with respect to doing engaged work, the qualitative approach we discuss here is crucial for understanding the practices and conditions that facilitate broader uptake. Scholarship on research evaluation demonstrates that in-depth interviews constitute the most commonly used and powerful method for identifying the pathways or mechanisms of impact, which is precisely what this paper aims to do (Donovan 2011; Spaapen and van Drooge 2011; Pedersen et al. 2020). Of course, the use of mixed methods is ideal as it allows researchers to look for points of convergence (Donovan 2011; Penfield et al. 2014). Thus, our approach is well aligned with best practices in the research impact literature given the goals of our project.

One of the main findings of our study was the important role of face-to-face interactions with scientists, policymakers, and other stakeholders when it came to influencing their thinking or practice. Such interactions generally played a more direct role in the uptake of participants' work than did publications in peer-reviewed journals. Furthermore, when participants did discuss publications and their citations as a pathway to impact, they typically referred to publications in *science* or *science policy* journals. Almost no one pointed to publications in philosophy journals or presentations in philosophical venues as direct pathways to broader impacts. These findings challenge the 'trickle-down' model of impact,

[1] The survey data are reported and discussed in Plaisance et al. (2019), though we draw on those data in this paper to highlight points of convergence between the survey and interview findings.

which suggests that excellent academic work will eventually be picked up by those to whom it is relevant (Frodeman and Briggle 2016). Rather, interpersonal engagement is more likely to lead to 'productive interactions' that facilitate uptake (Spaapen and van Drooge 2011; Molas-Gallart and Tang 2011; Muhonen et al. 2020).

While these findings may not seem terribly surprising to some, they nevertheless highlight a troublesome tension in philosophy of science: namely, that the types of activities philosophers of science are typically trained, encouraged, and rewarded to do (such as publishing in philosophy journals) are not well aligned with the activities that are most likely to increase philosophy's extra-disciplinary impact. What's more, this tension exists not just with respect to broader impacts themselves, but also with philosophers' own stated goals. As our interviews and survey data indicate, many philosophers of science personally value direct engagement and think that having a broader impact is an essential goal of the discipline. Thus, for many philosophers of science, there is a remarkable lack of alignment between the goals they espouse and the predominant disciplinary incentives. Our hope in reporting the findings from our own study is that it will help philosophers recognize the essential role of direct engagement with non-philosophers and find ways to facilitate and reward such approaches. (This does *not* mean, however, that more traditional modes of knowledge production and dissemination should not be valued. In fact, as Plaisance (2020) argues, such work is essential for doing broadly engaged work.)

This paper has multiple aims. First, we seek to advance philosophical scholarship on engaged philosophy of science (e.g., Fehr and Plaisance 2010; Douglas 2010; Cartieri and Potochnik 2014; Frodeman and Briggle 2016; Brister and Frodeman 2020; Plaisance and Elliott 2021). We do so by providing data that answers key questions raised by these and other scholars, and which can empirically test their claims. In particular, our research aims to improve our understanding of the ways philosophers of science can and do influence scientific practice, policy, and public engagement with science. Illuminating these pathways to impact is essential if we want to determine how best to broaden our reach. Furthermore, by identifying these pathways, we have uncovered a lack of alignment between at least some of the purported goals of the discipline and the predominant incentive structures. Towards the end of the paper, we briefly discuss some strategies for navigating this tension; we hope that philosophers who are interested in increasing their broader impact can make use of this research to inform their approaches. Finally, we hope that our study can also serve as a model for impact assessment.

Our paper is organized as follows. In Sect. 2, we provide an overview of our methods. In Sect. 3, we present and discuss key findings related to the types of impacts philosophers of science are having, the most common pathways to impact, and the value philosophers place on ensuring their work makes a difference to those for whom it is relevant. Section 4 situates our findings in recent scholarship on research impact evaluation and addresses some of the central issues in studying broader impacts. Finally, Sect. 5 unpacks the implications of our findings for individual philosophers and the discipline as a whole, offering advice for how we might better align our approaches with our various goals.

2 Methods

To conduct this study, the lead author assembled an interdisciplinary research team that included a philosopher of science, a philosophy graduate student, and a social scientist with expertise in quantitative, qualitative, and mixed methods research. This meant our team had insider knowledge of the culture of philosophy of science as well as the ability to design studies that meet rigorous standards of social science research. Over the course of our study, we interviewed 35 philosophers of science, representing diverse genders, countries, institutions, and areas of specialization (see Sect. 2.2 for demographic information). Below, we describe our approach to developing interview questions, recruiting participants, conducting interviews, analyzing the data, and employing strategies to validate our findings.

2.1 Development of interview questions

Before developing our interview questions, we conducted a large-scale survey of philosophers of science regarding their attitudes, experiences, and values with respect to doing broadly engaged work, and used the responses to inform both our interview questions and recruitment criteria (see Plaisance et al. 2019 for a discussion of the survey results). Next, we created an interview guide for conducting semi-structured interviews, which consisted of both open- and closed-ended questions and discussion prompts that the interviewer used with each participant. The advantage of semi-structured interviews is that they are flexible enough to give participants freedom to express their own views and raise new topics, while also enabling researchers to identify patterns across cases (Aurini et al. 2016; Pedersen et al. 2020).

We asked participants a wide range of questions to understand the larger context of their work, including their experiences disseminating their work outside philosophy and/or interacting with scientists, policymakers, or others. We specifically asked about the types of impacts they think their work has had outside the discipline. This allowed us to examine connections between the approaches philosophers took and the broader impacts they identified. Below are a few examples of the questions we asked:[2]

- What are some of the ways you've disseminated your work outside philosophy?
- Which of those do you think were the most fruitful and why?
- Do you think your efforts were successful? (What does 'success' mean to you?)
- Have you collaborated with anyone outside philosophy? How did that collaboration get started? Were some collaborations more fruitful than others? What do you think made them more fruitful?
- In what ways has your work been given uptake by non-philosophers?

[2] Note that these questions were posed in a semi-structured way and followed a sequential design based on the framework proposed by Small (2009).

- Have you seen any concrete ways that your work has influenced scientists' (or others') thinking or practice?
- What do you see as your role with respect to science?

We pilot tested our questions by interviewing three philosophers of science, after which we debriefed and revised the interview guide.

2.2 Recruitment, interview protocol, and participant demographics

We used a purposeful sampling strategy to recruit participants who we thought would have substantive views and/or experiences that could inform our investigation.[3] We began by identifying philosophers of science who had responded to our survey and indicated that they were willing to be contacted for a follow-up interview; we then looked for those who had interesting responses in the comments sections of the survey and/or who had successful engagement with or uptake by non-philosophers. This produced a long list of potential interviewees. Since we were conducting our first round of interviews at the 2016 meeting of the Philosophy of Science Association (PSA), we looked for those on our list who would also be at the PSA. We contacted several philosophers of science by email and scheduled interviews with 17 participants over the four days of the meeting (thus, this group comprised about half of our total sample). In advance of each interview, we did preliminary research to better understand each participants' educational background, career trajectory, and experience they've had disseminating their work to or collaborating with non-philosophers. This allowed us to tailor the interview guide and ask more informed questions.

At the beginning of each interview, we reviewed the information and consent letter with participants and gave them an opportunity to ask questions about the study or the process of consent.[4] Interviews were approximately 90 min in length, with variation depending on how much a participant wanted to share (ranging from 1 to 2 hours). After each interview, our team discussed some of the most interesting responses, highlighting emerging patterns that we could examine in subsequent interviews (either as further support for the pattern or a negative case that called it into question). After the PSA, we had each interview transcribed and uploaded into qualitative data analysis software.

Before conducting additional interviews, we rigorously analyzed the data from the PSA to identify significant patterns—e.g., between particular ways of disseminating one's work and participants' perceptions of the broader uptake of that work (see below for a description of our data analysis strategies). At this point, our

[3] Notably, purposeful sampling is not meant to be representative (which is why we separately collected quantitative data via the survey), but it is best for understanding context and identifying processes and pathways (our primary goal for this study). While a full discussion of sampling methods is beyond the scope of this paper, readers interested in current best practices can consult Creswell and Poth (2018).

[4] Our study was reviewed by and received clearance from the Office of Research Ethics at the University of Waterloo (ORE #21711/30938).

analysis suggested we had not yet reached saturation (i.e., later interviews were still producing new insights); thus, we recruited additional participants. The lead author visited three universities in North America to interview another 10 philosophers of science, representing several areas of specialization (e.g., philosophy of biology, philosophy of physics, and philosophy of medicine). These interviews also lasted about 90 min.

Subsequently, as part of our purposeful sampling strategy, we examined our sample and looked for gaps to determine whom else we might want to interview. These included philosophers of science who have had success with the broader uptake of their work and/or who have collaborated with scientists or policy makers, as well as pre-tenure philosophers of science (our sample thus far was mostly tenured professors). We conducted five additional interviews via Skype, at which point we determined that we had started to reach saturation with respect to most of our research questions. (We had not yet reached saturation regarding barriers for non-tenured researchers but decided to postpone additional interviews that would allow us to examine institutional and disciplinary barriers in depth in order to focus on examining impact pathways.)

As part of our recruitment strategy, we sought diverse representation with respect to gender, career stage, area of specialization, and country of residence. We interviewed a total of 35 philosophers of science (3 pilot interviews, 17 at the PSA, 10 at universities, and 5 via skype). Our final sample had the following characteristics:

- *Gender*: 16 women and non-binary participants, 19 men.[5]
- *Career stage*: 3 postdoctoral fellows and individuals with non-academic careers, 3 assistant professors, 9 associate professors, 18 full professors, and 2 professors emeriti.
- *Areas of specialization*: 13 philosophy of biology, 10 philosophy of psychology/neuroscience, 7 philosophy of physics, 5 philosophy of medicine, 5 philosophy of the social sciences, 5 science and values (note that some participants identified with more than one area of specialization).
- *Country of residence*: 6 from the UK, Europe, & Australia; 9 from Canada; and 20 from the United States.

2.3 Data analysis and validation strategies

To structure our analytic strategy, we drew on widely-used qualitative research guidelines, which primarily involved coding transcripts and looking for patterns in

[5] Note that gender was determined based on participants' pronouns at the time of the interview. In cases where a participant used gender non-binary pronouns or where their pronouns had changed, we asked which category they felt better reflected their gender identity at the time of the interview. We decided not to list the specific number of non-binary individuals that we interviewed in order to protect participants' identities. Furthermore, we chose not to associate demographic information with participant quotations when reporting our findings as doing so would likely have made certain individuals easier to identify.

the data.[6] Our first step was to create a list of codes that described particular aspects of participants' responses (e.g., 'attend scientists' lab meetings', 'publish in science journals', and 'learn the language of another discipline'). To develop this list, we drew on notes from the interviews, previous knowledge of issues relevant for our study (e.g., barriers philosophers of science face when trying to disseminate their work more broadly), and initial readings of the transcripts. Members of the team worked separately to highlight excerpts of transcripts that fit with one or more codes, then met to compare results and improve the list of codes. We did several iterations of interviewing, coding, and discussing patterns and themes until we reached saturation.

The lead author used the codes to identify excerpts of interviews where participants discussed the impact of their work. This allowed the author to delve deeper into the preliminary findings that emerged through the coding process and team meetings. We also looked for negative cases that might contradict the patterns and themes we identified. Doing so not only served as a validation strategy (see below), but also enabled us to construct a more nuanced understanding of our findings and generate data-driven hypotheses regarding pathways to broader impacts.

We employed several strategies to evaluate and validate our findings (see Creswell and Poth 2018, chapter 10). These included: revisiting the data to look for negative cases; debriefing with peers and/or the research team; triangulation with other data sources; and seeking participant feedback. Notably, since we had a diverse research team in terms of career stage and disciplinary background, we also had diverse perspectives in the evaluation of the findings. The mixed methods approach of our larger research program also gave us quantitative data we could use to triangulate our findings. Finally, we discussed our findings with a few of the participants and presented our research at the Public Philosophy Network (PPN) in 2018, where we received feedback on the study. This was particularly useful, as our study's stakeholders, participants, and audience all happen to be the same community—namely philosophers of science (as well as philosophers more generally).

3 Findings

Our analysis revealed several themes in participants' discussions about their broader impacts (or lack thereof) in science-related domains. These themes clustered around three general topics: the *types* of impact participants have had, the *pathways* through which impact occurred, and participants' *desire* or *motivation* to have a broader impact. We discuss each of these topics below, noting the ways in which they tend to be intertwined (e.g., the type of impact one is trying to have will likely affect which pathways are most promising).

[6] For methodological overviews, see Miles et al. (2013), Aurini (2016), and Saldaña (2018).

3.1 Types of impact

Participants discussed several types of impact their work has had on various individuals and communities, including scientists, policymakers, stakeholders, students, and interested publics. Six major categories of types of impact were represented in the data.

1. *Analyzing concepts or issues in a scientific field*: Many participants discussed applying their philosophical skills of analysis to scientific concepts or issues. Examples included: clarifying conceptual muddles in scientific work; helping scientists articulate research questions in a more meaningful way; and analyzing the nature of scientific disagreement (which can enable scientists to avoid talking past one another).[7] One participant illustrated several of these impacts when reflecting on their informal collaborations with scientists:

> Of the couple of [scientists] I'm thinking of, it does seem like over the course that I've known them they've been able to better articulate [their ideas]. And I mean, that's what philosophy's skills are all about in the first place. It's having a way to articulate those assumptions, to articulate what your research questions are in really meaningful way and be able to disentangle where you and somebody else are disagreeing.

Another talked about how their analyses helped scientists improve their practice:

> I think [my work] definitely helped [scientists] in trying to understand what the nature of these experiments are, how the nature of that data contributes to causal hypotheses and their experimental justification, and how you might then use that to plan better experiments.

Interestingly, in terms of broader impacts, most of the work on conceptual analysis seemed to be aimed at practicing scientists rather than policymakers or lay publics. This makes sense, since scientists are best positioned to actively change the way they understand or use particular concepts (and, as others have argued, the meanings of scientific concepts are typically tied to the way scientists use them; e.g., Collins and Evans 2007; Plaisance 2020). However, the interviews also provided examples of philosophers drawing on already published conceptual analyses (either their own or those of other philosophers) to inform their discussions with policymakers, as discussed under (5), below. (See Shrader-Frechette (2010) for a discussion of how conceptual analyses can be used to improve science and inform policy.)

2. *Identifying problems with scientific methods, inferences, and explanations, and offering alternatives for scientists to consider*: This was one of the most common categories, which is perhaps unsurprising since these types of analyses are precisely what philosophers of science are trained to do. They included:

[7] As an example of analyzing scientific disagreement, an anonymous reviewer suggested that philosophers of science could identify specific scientific controversies that turn on different philosophical assumptions and show how philosophical reflection clarifies these controversies. Examples include examining the scientific status of string theory, analyzing conceptions of race and species, and illuminating conflicting notions of reductionism in chemistry. Indeed, some philosophers have been doing exactly this sort of work.

identifying hidden assumptions in scientific research; suggesting alternative ways of collecting or analyzing data; identifying mistaken inferences; offering alternative explanations for research results (alternatives that were often made visible after philosophers highlighted problematic assumptions underlying the research); and suggesting alternative research questions that can advance the science and/or lead to more socially responsible research. (See Kourany (2010) for an in-depth discussion as to how philosophers of science can do the latter.) One participant explained how their analysis led to theoretical alternatives that had been taken up by scientists, but who had yet to apply those alternatives in their experimental work:

> We identified an error that many of the [scientists'] models were making that made it look like communication required a certain feature in order to evolve, and we suggested that: (a) that's not required because it would make evolution of communication very difficult, and (b) we identified a number of alternative theories to the traditional theory. And they're still just theories but we're starting to see uptake by people saying that this is a potential theory. No one has done an empirical test to confirm or disconfirm it but it now seems to be on the map of "here's an alternative" and "here's a problem with the traditional theory," so we're starting to see some uptake of the idea that there's a problem with the traditional theory and there are at least some alternatives that can be considered.

3. *Highlighting the role of values in science*: Over the past several years, philosophers have published insightful work on the role of values in science (e.g., Douglas 2009; Elliott 2017; Brown 2020), and on the ways the makeup of a scientific community can affect the values that drive scientific research (Longino 1990; 2002). Several participants talked about how they educated scientists about these issues, e.g., by helping scientists identify and unpack ethical-epistemic issues in scientific decision-making. One participant had the opportunity to collaborate with scientists and train them how to identify values in their research. As a result, they said:

> The whole team [of scientists] is now able to do a pretty good job of identifying some of these epistemic-ethical issues. And that's a real change. When we started […] a lot of the scientists would scratch their head and say, "Huh?" And now it's happening and changing how they set up their models.

Another described their efforts via social media to help scientists understand how social diversity enhances scientific research: "I think I've seen a more conscious link, at least in the scientists I know, between the efforts to diversify the scientific field and their understanding of why that's important."

4. *Contributing to the development of new scientific knowledge*: A few participants mentioned how their work advanced scientific theory or methods. One participant challenged scientists' way of doing their data analysis; later, at a science conference, they approached a scientist and said, "Hey, [I] noticed you did the data analysis differently," to which the scientist said, "Yeah, because you […]

were right." This same participant also convinced a scientist to change his theoretical framework. As the participant tells it:

> [A scientist has] got these great experiments. I think his theory's not quite right, so my talk is going to need to challenge him, do the Young Turk thing. I'm going to challenge him and I'm going to get this new theoretical interpretation of his results because I know he's going to be [at the conference]. So, I do it and get a little bit of feedback and afterwards, in the break, [the scientist] comes up to me and he goes, "Hey, great talk." I was like, "Oh, I kind of expected you to push back about the theory." He goes, "No, I don't care about the theory. Yours makes more sense and it fits the data just as well so, yes, sure, sounds good. Do you mind if I start adopting that?"

As we discuss below, many participants mentioned these sorts of face-to-face interactions when talking about the pathway to having an impact (Sect. 3.2).

5. *Enhancing science policy and legislation*: Rather than discussing how they've influenced *scientists'* thinking or practice, some participants described ways they helped *policymakers* understand and appropriately apply specific scientific findings, or how they shaped policy and legislation. One participant described their role in crafting guidelines that led to stronger provisions for governmental use of data. The enthusiasm with which they described this experience suggested that this work constituted some of this participant's most meaningful contributions of their career. Another participant explicitly told us that the "most useful thing I've done as a philosopher of science is probably being on lots of committees that have formulated reports that supposedly fed into legislative processes." Not only are philosophers of science using their knowledge and skills to enhance science policy, but in some cases they view these activities as some of the most valuable work they have done, as we demonstrate in Sect. 3.3.

6. *Improving science education*: Finally, it was interesting to see that several participants discussed leveraging their expertise to improve STEM education. One participant referenced the important role philosophers of science played in the Dover trial (Kitzmiller vs. Dover Area School District), serving as expert witnesses regarding whether intelligent design constitutes a scientific theory (spoiler: they argued in the negative). Others talked about the ways they've influenced science students through their teaching:

> I have a rule that whenever I'm invited to do something connected with education, I always say yes. I turn down lots of other stuff, but education is really valuable and in this case the connection is from philosophy of science and psychology of science to science education. And there I think the role for philosophers is really important because of issues like demarcating science from pseudoscience, how you evaluate theories, hypothetico-deductive methods versus more inductive methods. […] These are all philosophical questions that philosophers have a lot to contribute, so there's lot of ways in which philosophy should be useful to those fields. But of course, then you have to worry about the career path. It's easier to do this stuff after tenure than before.

Across all six of these categories, philosophers' efforts seemed to be aimed at a similar goal—improving others' understanding, practice, and/or application of scientific research. Moreover, while most of the literature on the broader impacts of academic work focuses on *research* impacts, it was interesting to see that many participants referenced their teaching, supervision, and service commitments as ways they had influenced individuals and communities outside the discipline. What's more, there was a wide range of audiences that participants mentioned besides scientists, such as policymakers, legislators, funding agencies, community stakeholders, STEM students, and various publics.

One of the next questions we examined was *how* philosophers' work got into the hands of those who could use it. In other words, what were the mechanisms through which philosophers influenced these various audiences? We present and discuss our key findings below.

3.2 Pathways to impact

One of the most striking findings from our data was that the majority of participants talked about *face-to-face (or interpersonal) interactions* as the main pathway through which their work had a broader impact. Conversely, almost no one pointed to publications in philosophy journals or presentations at philosophy conferences as the means through which their work was taken up directly; rather, such presentations and publications were typically only indirectly useful when it came to extra-disciplinary impacts. The benefit of philosophical publications was primarily in that they led to invitations to speak to a scientific community, collaborate with scientists, or help shape science policy, all of which enabled philosophers to have a direct impact. As some participants emphasized, the more important pathways were either "upstream" or "downstream" with respect to one's publications. Even when participants did mention the role of publications in having a broader impact, these were almost always publications in science journals, many of which were co-authored with scientists, as we discuss below.

Several participants talked about the "upstream" impacts of their research, referring to conversations and interactions that took place before they completed and published their work.[8] These discussions highlighted the crucial role of talking with scientists (and others) directly, often in person. One participant highlighted the importance of attending science conferences and workshops, through which they made long-term connections with scientists to whom their work was relevant:

> Before you get to the publication stage, I find that's often where there's a lot of [uptake]. There have been lots of options for me to disseminate to physicists

[8] Fisher and Schuurbiers (2013) use this term a bit differently, with "upstream" referring to the research conceptualization and design phase, "downstream" referring to research outcomes, and "midstream" referring to everything in between. We have chosen to distinguish these stages at slightly different points along the research trajectory, though we note that neither delineation is perfect (e.g., research outputs for one project can become part of the research design for another). Our main goal in drawing these distinctions is to show how much impact happens separately from traditional publications themselves.

> at workshops and conferences […]. The informal response I've gotten to my work [includes] people emailing me after the fact, and sending me their drafts of things, and I think that's really been something where a lot of the uptake of my work has been.

Another participant also discussed the role of presentations at science conferences, claiming that it is in those spaces—rather than through their publications—where they have the greatest impact in scientific domains:

> I feel that most of the impact I have occurs prior to publication. The publication is the stamp of approval. It's the thing that now people can cite. When presenting my work, I've already done a few iterations before I bother to write it up for a paper, which means it's had most of the intellectual impact before it shows up in print.

Similarly, several participants identified impacts that occurred "downstream" from their publications. These arose from opportunities such as invitations to give talks to scientists, policymakers, or health professionals; requests to collaborate with scientists (e.g., after a scientist heard the participant give a talk at a conference, or after getting to know them through a student's PhD committee); and invitations from policymakers or legislators to help craft new policy. In other words, most of these impacts resulted from face-to-face (or at least direct) interactions with other individuals or communities. One participant summed it up well:

> The most impressive impacts that [my] work had did not show up in other journal articles that talked about it, they showed up downstream. […] I got invited to write a kind of a best practice guide for [health professionals] […] So that to me felt much more like a meaningful downstream effect than just like so-and-so now cites our paper, because the way these medical citations work they cite so many things and everything gets cited so many times, so often the citations are kind of cursory.

These opportunities often came about as a result of shared networks—for example, a scientist who happened to be familiar with a philosopher's work would suggest to their colleagues that they reach out to that philosopher for help with a particular issue. Serendipitous encounters also played an important role; in a few instances, participants mentioned meeting a scientist through a shared service activity, where they discovered the mutual relevance of their work and decided to collaborate.[9]

Participants did discuss how publications led to broader impacts, though the role of publications tended to be indirect. In particular, publications in philosophy journals were often cited as a factor that led to *opportunities* for interaction with scientists, policymakers, or other stakeholders, where a non-philosopher had read a participant's publication or seen a citation of it, leading them to reach out to the participant to solicit their expertise. When participants pointed to citations of their work as evidence of uptake itself, however, they almost always referenced

[9] See Holbrook (2019) for more on the role of serendipity in designing high-impact research.

their publications in science journals (or interdisciplinary journals in which scientists publish as well). As one participant noted, "I feel the more important work I'm doing is being published in the more scientific journals." A few were adamant that such publications were crucial if one wanted to have an impact in scientific domains:

> If you want to have an impact you can't publish in a philosophy journal, it's not likely [to have a broader impact]. But I've published a lot in interdisciplinary journals […] probably my one single-authored paper that has had the biggest impact I published in *Behavioral and Brain Sciences.*

These findings were in line with our other research that investigated citation patterns regarding articles published by philosophers of science. We found that scientists were much more likely to cite philosophers' publications that appeared in science journals (or interdisciplinary journals where scientists publish) compared with those that appeared in philosophy journals, indicating little disciplinary cross-over in journal publications (McLevey et al. 2018). For those who want their work to be given uptake by scientists, disseminating directly to science venues seems to be more effective.

In addition to disseminating their work to scientific communities, some participants co-authored with scientists as well.[10] We asked one participant whether they thought part of the successful uptake of their work was because it was co-authored with a scientist. Their reply?

> Oh, heavens, yes. There's no question about that. […] If I had written it by myself, it probably wouldn't have been as significant. […] Because the co-author has standing – she's a rockstar in her community and has a lot of visibility. I understand that it's her visibility in that community that did the most to get an audience for this paper. But it was nonetheless important that it was co-authored with a philosopher.

Later, this participant explained that their publication led to a day-long symposium focused on their collaborative work. The participant described this event with excitement: "We had about 100 people in the room. It was amazing and deeply gratifying." This example highlights the potential benefits of co-authoring with researchers outside one's discipline, namely, the opportunity for expanding one's research network, which can increase the broader uptake of one's work. Indeed, recent research on co-authorship teams across 21 different scientific fields finds consistent evidence that access to a moderate amount of novel information—and being in a position to bring that novel perspective to a team—is a consistently strong indicator of high citations over the course of one's career (e.g., Graham et al. 2021).

[10] Our survey data suggested that co-authoring with scientists was pretty common, with just over half of respondents reporting that they had experience co-authoring manuscripts with scientists. The survey sample was skewed towards tenured professors, but the relatively high amount of cross-disciplinary collaboration was nevertheless surprising, especially given the common narrative of philosophy as a 'solo author' discipline (e.g., Frodeman and Briggle 2016).

A final avenue for influencing scientific domains was via education—either through teaching science students about the epistemic (and ethical) aspects of scientific research, or by working to improve STEM education more generally. As one participant explained:

> Most of the courses I teach that are in the philosophy of physics or philosophy of science category draw an audience of a handful of philosophy majors and then I get math and computer science students, physics students, biology students, psychology students, environment students. So, most of the students I draw for these courses are scientists, are training to be scientists. […] I think we can't forget that when we're teaching undergraduates that's also an important point at which we can influence their future paths […] the ones who don't go on to become philosophers can at least from an early stage in their careers have a good understanding of what philosophy can contribute to doing science.

Notably, much like the activities discussed above, this form of impact also typically involves direct interaction with others.[11]

The findings above suggest that *direct engagement with relevant stakeholders* is more effective in bringing about the broader uptake of participants' work than are publications in peer-reviewed journals (and, in particular, more traditional philosophy journals). This seems to be the case especially with regard to actually influencing scientists' thinking or practice. Several participants made precisely this point. One said, "I think clearly what philosophers of science write for other philosophers of science is almost never helpful to non-philosophical communities. It's addressing problems the way philosophers address problems." Another noted, "I don't think reading philosophy journals are at the top of scientists' to do list." And a third put it bluntly: "I don't know anybody who's written a paper [in a philosophy journal] and then suddenly [scientists] are doing it differently." Among our 35 participants, one disagreed with this view, suggesting that the relevant scientists (for this participant's work) would likely read work in philosophy of science journals. However, they later explained that the scientists they had in mind were theoretical biologists (who often publish in journals like *Biology & Philosophy*), and added: "the scientists I interact with might be an idiosyncratic group—they're willing to interact with philosophers and see value in what philosophers are doing; sometimes they don't even realize the people they're interacting with are philosophers; their role is more or less continuous with theoretical biology."

It is important to note that publications in philosophy journals are not irrelevant when it comes to broader impacts. In many cases, they provide an indirect means to impact (e.g., via invitations to work with scientists or policymakers) and can be what "gets philosophers in the door." They also provide philosophers with opportunities to develop the very work that ends up being useful to other communities. At the same time, there isn't good evidence that philosophy publications by themselves are the main driver of impact nor that those are the publications that tend to establish philosophers' reputations outside the discipline. As our other research suggests,

[11] For a detailed case of the broader impacts of teaching, see Shrader-Frechette (2010).

publishing in *science* journals is actually more effective in being recognized as a relevant expert among scientists (McLevey et al. 2018).[12] Regardless of the venue in which philosophers publish, one of the key findings from our interviews is that citation by itself is not a good measure of influence. (This is precisely why multiple methods are needed to examine impact.) As some participants noted, even when scientists do cite one's work, that does not guarantee they are engaging with or taking up the philosopher's argument or main point. (One participant noted that citation norms in science tend to be different than in philosophy in that science publications typically include many more citations but less in-depth engagement with the literature being cited.) Similarly, it is possible to have an influence on a scientist's way of thinking via informal conversation that never leads to a citation.

In sum, the most common pathway to having an impact in science-related domains, according to our data, was as follows: (1) present work at a science conference or publish in a science journal → (2) be invited to speak to scientists or meet with policymakers → (3) collaborate with scientists or policymakers to shape their practice or policy, or even publish together. Conversely, our data suggests that one of the least common pathways is (a) publishing in a philosophy journal → (b) having it read by scientists, policymakers, or other stakeholders → (c) changing thinking or practice in those domains. While some readers may not consider this finding to be incredibly surprising (indeed, many empirical findings seem obvious once we know the answer[13]), it highlights the fact that the typical training and reward structures in philosophy are not aligned with the activities and approaches that are most likely to lead to broader impacts of our work. In fact, the "gold standard" when it comes to research, namely publications in philosophy journals, seem to be least likely to increase our impacts in science-related domains. While this certainly does not negate the importance of philosophy publications (partly because publishing in philosophy journals can facilitate broader impacts and partly because broader impacts are certainly not the only worthy goal), it does raise the question as to whether we ought to rethink how various activities are and should be evaluated within our discipline. We discuss this more in Sect. 4; but first, we turn to our last set of findings—the importance of broader impacts to philosophers of science.

3.3 The desire and obligation to have a broader impact

In addition to discussing the types of impacts they had and the activities that led to those impacts, some participants expressed a strong personal desire for their work to influence individuals and communities outside philosophy. A few even told us that their most meaningful work was that which directly shaped thinking and/or

[12] Notably, this study only looked at citation patterns with respect to peer-reviewed articles. While its findings are in line with our interview data, there is some evidence that books written by philosophers are given broader uptake relative to philosophy journal articles (e.g., Heather Douglas's (2009) book on *Science and Values* and Helen Longino's (1990) *Science as Social Knowledge*).

[13] This is taken from sociologist Duncan Watts' (2011) book, *Everything is Obvious: Once You Know the Answer*.

practice in other domains. One participant pointed to their collaborations with scientists as an example: "The most important work I do is when I'm n^{th} author on a science paper, where the content of the science paper is different than what it would have been if it didn't have a philosopher on it." Another put it more bluntly: "I get depressed if my stuff is just of interest to philosophers." These views were in line with the results from our survey data, which suggest that those who highly value more engaged work are not in the minority (Plaisance et al. 2019). Of those we surveyed, almost all respondents (97%) said that it was at least somewhat important to them that scientists read and/or make use of their work, with the majority (63%) rating it as 'very important'. Most respondents (64%) also listed policymakers as an important audience, with some (20%) saying it was very important that policymakers utilize their work.

When we asked interview participants which impacts were most meaningful to them, they tended to share examples such as getting scientists to recognize their ethical obligations, shaping science policy, and educating the next generation of scientists, engineers, and health professionals. In each of these cases, these outcomes were the result of direct engagement with target communities. (As we discuss in the next section, this does not necessarily mean that direct engagement is necessary for such outcomes—it may be that participants are simply more aware of them when they come from direct engagement, given the opportunity for feedback. However, we also conclude that there is good evidence that such approaches are more effective at facilitating broader uptake.)

Some interview participants went a step further, arguing that philosophy of science, as a discipline, has an *obligation* to ensure it has broader impacts. One individual suggested that philosophers of science should think more about how to contribute to science and try to engage with scientists on their terms when doing so:

> For me, it's establishing a two-way street; it's establishing that we take things from the sciences, which I think philosophers do very well, but that we also give back. There are things that we do that will influence the development of science and I think it's *that* direction that there's not enough of.

Another took a stronger stance, suggesting that philosophers are *accountable to* scientific communities:

> If there were no science, there would be nothing for us to do; we'd all be out of a job. That means, if that's true, our work is parasitic in this deep way on other disciplines [such] that we should have accountability to the disciplines that we are parasitic on, that we should care what they think about our work. We should try to communicate key arguments to them.

Yet another participant agreed that philosophers should be advancing science, but argued that it doesn't always make sense to classify the contributions philosophers make as being 'philosophical' or 'scientific'; rather, we should focus on addressing particular problems:

> I don't see it as biological contribution or philosophical contribution. I have this view that there's a certain body of work or problem space. You can call it

> philosophical conceptual analysis, you can call it theoretical work in biology, it doesn't matter how you label it, but it's the same problem space.

When we asked participants about what they thought were appropriate roles for philosophers of science, only one of the 35 participants said that philosophers of science should *not* aim to have an impact on the content of science (e.g., by advancing scientific theory). Instead, that participant argued, philosophers should examine the social impact of science and aim to improve science policy.

> I think we can have an impact by interacting with scientists; we can have an impact on the way they present their work to the rest of society. […] I think this is our main responsibility as philosophers of science rather than try to improve this or that theory in science. I think scientists are able to do that by themselves but they might not be able to have a proper view of the activity and to have a proper impact on science policies, so it's that kind of action we should follow.

Interestingly, although this participant thought philosophers' roles shouldn't include contributing to the advancement of scientific research itself, they still thought philosophers should interact with scientists in order to understand how scientists present their work to society and for the purposes of evaluating the social impact of scientific research.

Again, our interview findings were well aligned with our survey data. For example, when survey participants were asked whether they thought philosophy of science, as a community, has an obligation to ensure it has an impact on science, over half of the respondents (60%) agreed. About the same number (62%) also agreed that the discipline is obligated to ensure it has a positive impact on society. While not everyone endorses such an obligation, it is worth considering how the discipline can support those who wish to disseminate their work more broadly or collaborate with those outside philosophy, as we discuss below.

4 Discussion: Reflecting on Impact

4.1 Summary of findings

The results of this study provide evidence that at least some philosophers of science have had significant impacts in a variety of science-related domains. This includes, but is not limited to, enhancing scientific theory and practice, contributing to science policy, and educating students and lay publics. Our study also adds to the growing evidence that many philosophers of science value broader impacts, with some even viewing this to be their most meaningful work. Moreover, a significant proportion of philosophers of science believe the discipline has an obligation to ensure it has an impact; thus, even those who don't share these goals arguably ought to support this work. Our interviews indicate that direct (or interpersonal) engagement is most

likely to bring about broader impacts.[14] Thus, it would be prudent for at least some individual philosophers to take up these approaches and for the rest of the discipline to support them, as discussed in Sect. 5, below. First, however, we turn to the literature on research impact evaluation to consider the nature of impact itself and various approaches to studying it.

4.2 What is impact and how can we identify it?

Thus far, we haven't explicitly interrogated the notion of impact itself. What does 'impact' mean, exactly? What are the best ways to track and evaluate it? How does our understanding of impact affect which assessment methods are most appropriate?

Simply put, there is no consensus on the meaning of 'impact' itself (Brewer 2011). Some conceptions operationalize impact in terms of research outputs, others in terms of user engagement, and yet others on changes in behavior. As John Brewer puts it in his paper, "The Impact of Impact", "all these have slightly different connotations and mean different things" (2011, p. 255). Frodeman and Briggle suggest moving away from using 'impact' altogether as "the term is too Newtonian, suggesting the effects of a car crash, when most outcomes are much more indirect and varied than that. Terms like 'influence' or 'sway' better represent the complex processes involved" (2016, p. 135). We agree with this point, though 'influence' itself can mean different things, so this doesn't completely solve the conceptual issue; furthermore, it does not tell us which method of assessment to use since influence is equally difficult to measure. While we do not have space to delve into these important conceptual issues here, we briefly discuss commonly used methods and frameworks for examining broader impacts to situate our approach and lend context to our findings.

One of the most well-known approaches for tracking research impacts are bibliometric techniques, such as examining citation patterns (Penfield et al. 2014). These approaches are often based on a 'passive diffusion' or 'trickle down' model of impact, especially when relied upon by themselves (see Frodeman and Briggle 2016, chapter 7.) While some view bibliometric methods as providing a more objective measure, they are in fact limited to capturing only certain types of impact (Donovan 2011; Penfield et al. 2014). Moreover, these methods typically lack the ability to uncover the processes that lead to impact or the ways in which the research being cited was actually used. One of our own interviews demonstrated how citations can be misleading, where scientists may cite philosophical criticism of their work but not actually engage with or address the criticism itself. As the participant put it, "I'm seeing that my work is starting to get cited by people who are doing [scientific] research, but they are not engaging with the arguments. […] They're citing us, but not actually doing anything about what we've criticized." In short, not only does a lack of citation not rule out an impact (that is, citations aren't *necessary*), but the presence of a citation also doesn't guarantee that the original work was taken

[14] See Plaisance (2020) for an in-depth discussion of how immersing oneself in a scientific community can lead to socio-epistemic benefits that include increased uptake of one's work.

up as intended (i.e., they are not *sufficient* indicators either). Despite these limitations, large-scale citation patterns can still provide clues as to where and how impact occurs and can be particularly insightful when used in combination with qualitative methods.

Survey methods can also be used to study research impacts. Again, they are limited in what they can detect, but they too can uncover important patterns. In particular, "surveys are useful for collecting data on different variables, such as motivations, perceived barriers and enablers, and different types of engagements between researchers and society" (Pedersen et al. 2020, p. 10). (Indeed, this is precisely why we used a survey to identify common barriers to broader dissemination and cross-disciplinary collaboration before conducting interviews.) Like bibliometric approaches, surveys aren't well suited to capturing contexts, but are useful when looking for population-level effects or when leveraged to inform qualitative approaches.

Recognizing the limitations of quantitative data, policymakers have begun to emphasize the importance of qualitative approaches. The UK, for example, recently developed the Research Excellence Framework (REF) to identify impacts that may not show up in citation or survey data. As part of the REF, philosophers in the UK have been asked to provide brief narratives of their societal impacts (Penfield et al. 2014; Hicks and Holbrook 2020). While these case studies allow researchers to document broader types of impacts, they are also quite limited in length, leaving no room for discussing *how* particular impacts came about—precisely the information that is needed for understanding impact pathways (Hicks and Holbrook 2020). Furthermore, REF case studies are typically written by different people, which makes it difficult to conduct cross-case comparisons (semi-structured interviews, like the ones we conducted, are better suited to this task).

Precisely because of these limitations, interviews have become the most commonly used method in assessing the societal impacts of research in the humanities and social sciences (Pedersen et al. 2020). As Penfield et al. (2014) put it, "Interviews allow informants to reflect upon critical conditions for creating impact, and interviewers can react and customize questions based on informants' responses. Using a structured interview guide allows comparisons between cases and projects, and may uncover motivations, enablers, or concerns related to the creation of impact" (27). Interviews are incredibly time-consuming, but their strength is in being able to capture the process of impact which can be quite complex: "Impact is derived not only from targeted research but from serendipitous findings, good fortune, and complex networks interacting and translating knowledge and research" (Penfield et al. 2014, p. 26). In short, if one's goal is to understand how broader impacts arise (e.g., in order to develop better strategies for increasing one's impacts), interviews are one of the best ways to achieve that goal.

4.3 From impacts to productive interactions

Literature in research impact evaluation goes beyond analyses of various methods for assessing impact—it also offers key theoretical frameworks for understanding

the nature of impact itself. One of the most insightful frameworks, which can help to illuminate our own findings, is centered around the role of 'productive interactions' (Donovan 2011). According to its creators, productive interactions can be understood as "exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant. […] The interaction is productive when it leads to efforts by stakeholders to somehow use or apply research results or practical information or experiences. Social impacts of knowledge are behavioural changes that happen because of this knowledge" (Spaapen and van Drooge 2011, p. 212).[15] These interactions can be direct (i.e., personal interactions, such as face-to-face encounters) or indirect (encountered through publications or other media).[16] As our interviews indicate, direct interaction often makes it easier to have a reciprocal exchange, whether it be through informal conversation at a conference or an active thread on Twitter. Furthermore, as Plaisance (2020) has argued elsewhere, reciprocal exchange is more likely to lead to uptake.

Because it is notoriously difficult to identify or measure impacts themselves, the productive interactions approach shifts the focus to identifying and examining key steps in the *process* of impact. This makes it particularly well suited to determining which impact pathways are most promising (Muhonen et al. 2020). The framework thus has an enlightenment function: "it is oriented towards learning and improving rather than judging and accounting" (Spaapen and van Drooge 2011, p. 216). By focusing on processes, this approach can reveal intermediate impacts, including the small steps that are often necessary for creating more significant changes within a community (Spaapen and van Drooge 2011). As one of our own participants noted, when it comes to having broader impacts, "it's always little drops in a bucket." Another participant pointed out that scientific communities in particular are quite large, making it difficult to change the intellectual agenda of a field. Instead, "we can hope to be part of the conversation and maybe change the minds of some of the people and maybe indirectly then they'll have an impact."

By applying it to our study, the productive interactions framework can help reveal the informal contributions philosophers of science have made outside the discipline, which have led to changes in scientific research, application, and understanding. It may also explain why Frodeman and Briggle's study of the applied philosophy literature failed to bear fruit. As Frodeman and Briggle themselves note, while some authors who published in the applied philosophy journals that Frodeman and Briggle looked at did discuss the social relevance of their work, Frodeman and Briggle "found no indications that the authors are actually involved in policy processes" (2016, p. 86). Yet, we know that at least some philosophers of science (and philosophers more generally) have been involved in policy, even working with policymakers to craft new legislation. Most likely, these cases were not detected by Frodeman and

[15] This framework is also referred to as 'SIAMPI', as it arose from a project on "Social Impact Assessment Methods for research and funding instruments through the study of 'productive interactions' between science and society" (Spaapen and van Drooge 2011, p. 212).

[16] Spaapen and van Drooge (2011) actually identify three types of productive interactions, adding *financial interactions* to the list. We have left those out here, as they are rarely (if ever) relevant when it comes to philosophical work.

Briggle's study as philosophers tend not to explicitly reflect on their processes in their published work (rather, such reflections are more likely to happen in informal venues such as conferences and workshops). Furthermore, these philosophers may not have been fully prepared to articulate their processes on their own. As Spaapen and van Drooge (2011) found, and as some of our interviews suggested, the interview process itself can help researchers to become more aware of how their interactions lead to changes in thinking and behavior.

The productive interactions framework has other benefits as well, including legitimization and positive reinforcement, both of which can facilitate strategies that are more likely to increase one's impact. As one of the participants in Molas-Gallart and Tang's study noted:

> [T]he very notion of such interactions as 'productive' provides a level of positive reinforcement which is helpful in encouraging researchers to engage with users. It also provides a legitimisation of the strategy of getting out and meeting research users, networking and attending/presenting at meetings – which we all know is important in terms of creating research opportunities, yet can often feel not quite like 'proper' academic work. (2011, p. 224).

This observation is highly consistent with what we heard from our participants. In some cases, activities like the ones mentioned above were associated with what participants described as their most meaningful work.

We hope the findings from our study will help to legitimize such activities and encourage interested individuals in taking them up. In Sect. 5, we discuss potential strategies for doing so.

4.4 Challenges to identifying impacts

As with all methods of studying research impact, the interview method we used—and the productive interactions approach more generally—is subject to biases and limitations. The most significant issue with conducting interviews is also its strength; namely, that interviews often make it easier to identify pathways involving direct interactions compared with more indirect ones (such as publications). Furthermore, while focusing on productive interactions can be fruitful, such activities are still only a proxy for impact. As Spaapen and van Drooge themselves put it, "it is not the productive interaction per se that is important, but the role it plays in the process of realizing social impact" (2011, p. 218). It is essential, then, to specifically ask participants not only what activities they engaged in, but also what evidence they have as to how that made a difference in the target community. This is precisely why we began our interviews by prompting participants to talk about examples of how their work has been given uptake, then later asking them for evidence of the concrete ways their work has influenced scientists' thinking and practice. Asking questions in this way enabled us to better trace the pathway from direct/indirect interactions to uptake to influence.

Some participants were able to point to evidence of broader impacts as we saw in the excerpts above (e.g., scientists adopting a participants' theory or making the

values underlying their research methods more transparent). However, other participants struggled when we asked them to specify concrete changes that resulted from their work. One participant said, "I don't know if it has [had an impact] or not. That's a really hard thing to say. I mean, I … you'd have to ask [the scientists]. It's hard for me judge whether what I've done or said has been influential. It's very difficult to judge the impact of your own work, right?" Another told us, "I try to make my work relevant to people outside of philosophy and it's hard to know when it's working." One possibility, of course, is that no impact had occurred in these cases. As Molas-Gallart and Tang note, "a productive interaction may not lead to an impact: after considering the research and its results stakeholders may not change at all their way of doing things, or the research itself may recommend that no changes are implemented" (2011, p. 219). Yet, we also know that one cannot infer a lack of impact solely from a lack of evidence. Indeed, researchers have demonstrated that a great deal of research impact may actually be 'disguised impact'—unrecognized and often invisible to the research creators (Brewer 2011).

Philosophical contributions, in particular, may be especially subject to the problem of disguised impact. As noted above, while there is no consensus on what impact means, it is often cashed out in terms of influence, which in turn may be cashed out in terms of some kind of change. But what counts as change or evidence of change? For example, suppose a philosopher identifies a tacit assumption underlying a scientific method, which relevant scientists then acknowledge (that is, they give it uptake); then suppose they critically scrutinize the assumption, but ultimately conclude that the assumption is warranted. On the face of it, it may appear as if no change has occurred. But this 'serious consideration' is precisely the sort of activity that Helen Longino argues can make science more objective (1990; p. 2002). While it may not lead to a change in scientists' *practice*, it does have epistemic consequences. In the example given above, those consequences include stronger warrant for the validity of a particular method, and thus stronger evidence for the results that the method generates. These consequences are important since generating reliable and trustworthy knowledge claims are not just about what findings scientists' methods produce, but the confidence we have in the claims that result.

Finally, it is important to note that having an impact does not mean producing a benefit: "A social impact may not necessarily generate a social benefit; it may not be socially relevant, or could be considered by those affected as having had negative rather than positive effects" (Molas-Gallart and Tang 2011, p. 219). Different stakeholders may have competing views on the value of a particular impact; where some see a benefit, others may see a "grimpact" (Frodeman 2017).[17]

While we were not able to eliminate all of the limitations and challenges discussed above, we were able to address some of them with our study design. First, as mentioned above, we intentionally asked questions in a particular order and using particular language that enabled us to better trace impacts from interactions (whether direct or indirect) to uptake to influence. Second, and more important, because our research team utilized a mixed methods approach as part of our larger

[17] We're grateful to Adam Briggle for bringing this concept to our attention.

project, we were able to compare the findings from our interviews with our quantitative data to look for areas of alignment and areas of conflict. Overall, we found significant alignment. For example, our citation analysis showed that publishing in journals of one's target community is more effective than publishing in philosophy journals; our survey data demonstrated that many philosophers of science care about having a broader impact, have been actively disseminating their work to non-philosophers, and have found their dissemination efforts to be successful. Of course, it would be ideal to query the relevant stakeholders themselves (indeed, a few participants suggested that we speak with their collaborators), which is the next phase of our research program.[18]

5 Discussion: Navigating the 'Troublesome Tension'

5.1 A troublesome tension

Regardless of its limitations, this study provides good evidence that interpersonal engagement is one of the most promising pathways to broader impacts (as does related research on the broader impacts of humanities research). It also demonstrates that at least some philosophers of science view broader impacts as an important professional goal. In fact, as our survey data show, many philosophers of science think that the discipline as a whole has an *obligation* to ensure that philosophy of science is having positive impacts outside the discipline. For those who disagree, and/or who are not interested in broader impacts themselves, interpersonal engagement may still worthwhile since it can lead to new philosophical insights (Douglas 2010; Fehr and Plaisance 2010; Tuana 2010; Plaisance 2020). Yet, despite evidence that attending to broader impacts is highly valued in the abstract, recent studies have found that research activities which don't directly lead to publications in philosophical venues are not typically rewarded (Hrotic 2013; Tiberius 2017). This is consistent with findings in the research impact evaluation literature where, as one study participant put it, "researchers felt they did a lot of useful 'stuff' without ever really having an intellectual peg on which to hang it" (Molas-Gallart and Tang 2011, p. 224).

In short, then, our study demonstrates that what is most effective in terms of increasing one's broader impact of their work is in tension with typical norms, practices, and incentives in our discipline. This is particularly problematic at a time when there is growing pressure for humanities research and other academic efforts to be more socially relevant. For disciplines in science, technology, engineering, and math (STEM), this pressure was made especially visible over twenty years ago with the introduction of the National Science Foundation's Broader Impacts Criterion, which required STEM grant proposals to explicitly address how their project would benefit society (Tuana 2010). More recently, as discussed above, the REF framework in the UK has emphasized broader impacts since its introduction in 2014 (Hicks and

[18] Notably, we recently received a grant to conduct this next phase, which will include interviews with scientists who have collaborated with philosophers.

Holbrook 2019), and Canada's Social Science and Humanities Research Council (SSHRC) has been increasingly emphasizing knowledge mobilization in their funding criteria, especially that which has the potential for wider social benefits.[19] Certainly, we are not advocating that all—or even most—philosophers of science ought to focus their efforts on broader impacts, but having at least some philosophers taking this approach can help connect important philosophical work to those who might benefit from it, and help demonstrate the field's broader relevance in the process.

One might ask why this troublesome tension exists. While we discuss several possibilities in more detail in Plaisance et al. (2019), there are a few possibilities worth considering here. First, as we noted above, our study (like any empirical study) isn't without its flaws and may have overestimated the role of direct interactions in fostering broader impacts. If this were the case, then the gap between the approaches that are most effective and those that are typically rewarded may not be as large as this study suggests. We believe that this explanation is unlikely given the consistency between our findings and those reported in the research impact evaluation literature. Alternatively, it could be that interpersonal engagement is more highly rewarded than we think. Indeed, our own survey indicated that perceived barriers may be larger than actual ones. However, it also indicated that actual barriers do exist, in line with findings from other studies of philosophy's reward structure (Hrotic 2013; Frodeman and Briggle 2016; Tiberius 2017). A third possibility is that most people do not realize how much of an enabling role direct engagement plays in increasing the uptake of one's work. If that explains a significant part of the gap, then we hope this study will motivate change. More likely, however, this tension exists because the norms and structures we have in place are "how things have always been done," and it is much easier to maintain the status quo than it is to effect real change. Again, we hope that the research presented here will help illuminate the problems with the status quo and highlight what types of changes are needed.

Of course, there are legitimate reasons for prioritizing publications in philosophy journals over and above research activities that are focused on interpersonal engagement with non-philosophers. One reason is that we want and need philosophers to advance knowledge in our own field. Another is that, when it comes to graduate students and early-career scholars in particular, philosophers need to engage with and have their work reviewed by other philosophers in order to develop expertise in the discipline and build a track record that other philosophers can evaluate for hiring, tenure, and promotion purposes. Indeed, this is likely why so many of our interviewees noted that they waited until tenure to do work that significantly engages scientific and other communities.

5.2 Potential solutions

How can we bring our approaches, training, and incentives more in line with our goals, aspirations, and desire to do work that has a positive impact on science and

[19] Personal communication, Ruth Knechtel, Office of Research, University of Waterloo.

society? That is, how might we begin to resolve this troublesome tension? The first step is to identify and better understand this gap. In particular, we need to determine which goals are important and which approaches are more likely to help individuals realize those goals. That is precisely the step we have taken here, and in our larger research program more generally (see Plaisance et al. (2019) for a more detailed discussion about the various goals philosophers of science endorse). Second, we need to highlight potential strategies for individuals, as well as for the discipline as a whole. While delving into the details of these strategies and how they might be implemented is beyond the scope of this paper, we offer some preliminary suggestions below.

We recommend three strategies that can be enacted at a departmental, institutional, and disciplinary level. The most obvious, and indeed the one that we have alluded to above, is to develop broader and more flexible criteria for hiring, performance reviews, tenure, and promotion. As Frodeman and Briggle point out, single-authored publications still tend to be the gold standard in our field and collaborative work is often frowned upon (2016, p. 117). Thus, more flexible criteria might include giving credit for philosophical work published in relevant but non-philosophical venues (e.g., science journals). Just because something is published in journals outside the discipline doesn't mean it's not philosophical or that it doesn't advance philosophical understanding; rather, it is better positioned to increase the chance that the philosophical work will influence those who are typically in positions to effect change. In addition, collaborative work should be valued, and valued appropriately. We hear far too often, both from participants and colleagues, that co-authored work counts for a small fraction of a single-authored paper (even though it often takes just as much—if not more—time, especially when authored with someone from another discipline, where important translational work must be done and differences in writing and publishing norms must be navigated).

We want to emphasize that these changes will need to be enacted by those in decision-making positions, not just left up to those who value this work. Also, having gatekeepers such as journal editors and philosophy association leaders on board will also help to advance this goal (Fehr and Plaisance 2010; Tiberius 2017). Again, this does not mean that publishing in philosophical venues should not be encouraged or even required. Indeed, we are not limited to two choices: incentivizing and rewarding *only* work that is disseminated in philosophical venues vs. recognizing and counting *all* scholarship in exactly the same ways. Rather, there is a middle ground that can be sought, where philosophical presentations and publications are required, but contributions made outside the discipline are also recognized as valuable work, especially since that work can help increase the broader relevance of our discipline (and, as noted above, enhance philosophical work in the process).

Another strategy for reducing the tension between our approaches and some of our goals is to include training for graduate students and early-career scholars in how to build networks, present at science conferences, talk with stakeholders, and collaborate. As Thagard (2006) points out, philosophers do not learn these skills (as opposed to students in STEM programs, who often have the opportunity to work in laboratory communities and co-author with other researchers). We also need to continue paying attention to the conditions that facilitate—and those that

block—broader impacts. This will enable us to identify barriers that need to be addressed and opportunities that might be leveraged. (This is precisely what Australia's recent Engagement and Impact Assessment (EI) approach aims to do, by assessing "societal impact through both tangible outcomes, but also the presence of institutional mechanisms promoting or enabling research impact with outcomes based on qualitative descriptions of how the institutions facilitated impact realization" (Research Council of Australia 2018, quoted in Muhonen et al. 2020, p. 36).)

Individuals who wish to increase their broader impacts can follow some of the approaches discussed by participants in this study by actively disseminating one's work to relevant communities. (Notably, not all philosophical work will be immediately relevant to others outside the discipline.) This might include publishing in science, science policy, or other journals; writing white papers; or disseminating one's philosophical publications to relevant stakeholders via social media. (The last option means you can publish in philosophy journals and still ensure that your work gets into the hands of those who can use it, though attention must be given to writing one's work in an accessible way.) Collaborating is a particularly powerful way to increase impact, especially for those who are aiming to publish in non-philosophy journals. Publishing with a scientist often requires extra work, but it may be more efficient than trying to figure out the publishing norms on your own.[20] In this respect, the advice from the Calgary Summit to "publish in science journals" and "collaborate with scientists" was spot on; we just need to think more carefully about what that entails and what challenges might arise in doing so (e.g., must one wait until tenure to do this sort of work?). Furthermore, this is only one set of strategies for increasing the broader impact of philosophy of science. As the interviews demonstrated, many philosophers have had significant influence in policy and education spaces as well.

We should also consider what specific strategies, activities, and attitudes are more likely to make someone successful in these endeavors. According to some of our participants, key factors include putting in the time to learn the relevant science or policy, a willingness to listen to others, the ability to understand others' positions and interests, and displaying epistemic humility (see Plaisance (2020) for a more in-depth discussion about the importance of relationship-building for facilitating broader impact). In fact, these suggestions collectively made up another theme from our interviews (one of the codes underlying this theme was labeled in the words of a participant: "don't be an asshole"). While this advice may seem obvious, some philosophers are quick to criticize (in fact, that is one of our key skills), and often do so without fully understanding the perspective of those whom they are criticizing, nor engaging in genuine dialogue. (Of course, in some cases, such understanding isn't necessary for generating useful criticism and there may be times when maintaining critical distance is beneficial. See Plaisance (2020) for a discussion of this tradeoff.) A related but separate strategy is to look for and leverage opportunities. Research

[20] One of our participants, a prominent philosopher of science, noted that despite being incredibly prolific in philosophy, they were unable to successfully publish in relevant science journals. They attributed this to the challenges of writing according to the norms of that scientific discipline. Notably, this participant had not attempted to co-author with practicing scientists.

has demonstrated that productive interactions often arise from serendipitous encounters (Donovan 2011; Spaapen and van Drooge 2011; Molas-Gallart and Tang 2011; Penfield et al. 2014). As Holbrook (2019) argues, however, that doesn't mean these are a result of pure luck—rather, one can strategically look for and act on promising opportunities. This might include taking actions that are likely to create more opportunities to begin with, as some of our own participants had done (e.g., attending relevant conferences outside philosophy, serving on PhD committees for students in other departments, and even co-teaching with non-philosophers).

Individuals interested in doing work that may not be rewarded may want to consider tracking their own productive interactions and trying to trace them forward to identify potential and actual impacts. In doing so, it is important to note that impacts can change over time and that they can be viewed differently be different stakeholders. (This is one of the benefits of the Field Philosophy approach advanced by Frodeman, Briggle, Brister, and others, as it requires working *with* relevant stakeholders and understanding problems from their perspective; this is just one among many approaches that a philosopher of science looking to increase their broader impacts might take.) One can also make use of altmetrics and other approaches to impact assessment (Penfield et al. 2014; Pedersen et al. 2020). These techniques will enable philosophers to highlight their impacts in ways that aren't captured by standard bibliometrics (e.g., citation alerts from Google Scholar).[21] It will also put early-career researchers in stronger positions when it comes to hiring, tenure, and promotion, which can alleviate some of the tension with the standard reward structure. Finally, we encourage philosophers of science, and philosophers more generally, to continue discussing and writing about their experiences, challenges, and strategies for increasing their broader impacts, in the spirit of the papers and chapters published in Plaisance and Fehr (2010) and Brister and Frodeman (2020). These reflections can contribute to our collective understanding as to how philosophical knowledge is and could be generated and disseminated, ignored or taken up.

The strategies we have suggested above are ones that can be implemented by individuals, departments, and disciplinary organizations (e.g., the Philosophy of Science Association) to a large extent. However, it is important to note that these solutions do not fully address deeper issues within the discipline itself nor the barriers that may arise for those to whom our work is relevant. For one, the findings discussed above invite fundamental questions about the goals of philosophy of science, and philosophy more generally, as well as what questions and approaches are considered legitimate within the field. We highlighted these issues in our survey paper, where we show that many philosophers of science think a wide variety of goals are appropriate for our discipline, including those that involve attention to broader impacts. Broadening the goals we value, the approaches we take, and the questions we see as legitimate may be particularly important for addressing the lack of diversity in our field as well (Allen et al. 2008; Haslanger 2008; Dotson 2012; Valles 2017).[22]

[21] We strongly advise those who are unfamiliar with these techniques to reach out to research librarians at their institution.

[22] Notably, Dotson (2012) pushes back against the entire "culture of justification" (see Plaisance et al. (2019) for a more detailed discussion of how her argument relates to our findings).

To achieve this latter goal, though, we will need to take the sorts of steps we recommended above (e.g., developing more flexible criteria for hiring, tenure, and promotion) as rigid and opaque expectations tend to exacerbate existing inequities in the academy (Matthew 2016; Strunk 2020).

Notably, these recommendations focus on what *philosophers* can do to increase their broader impacts (and achieve related goals). Of course, scientists, policy makers, and others face their own barriers to making use of philosophical work that is relevant to them. The incentive structures in science are not wholly different from those in philosophy, with a similar tendency towards undervaluing both interdisciplinary work and engaged scholarship that does not take the form of grants and peer reviewed articles. What's more, many scientists may not be familiar with philosophy of science (or, frankly, even aware of its existence); and a few are downright hostile or dismissive (e.g., see Pigliucci 2014). Thus, it is worth pursuing further research regarding the barriers and challenges to philosophy's broader impact that exist outside the discipline.[23]

6 Conclusion

This study enhances our understanding of how philosophical knowledge and insights are disseminated across disciplinary boundaries and taken up in scientific domains. Our findings indicate that direct, interpersonal, and often face-to-face interactions are associated with greater impacts outside the discipline. Furthermore, our interviews suggest that many philosophers of science deeply value the impacts they've had among scientists, policymakers, and other relevant stakeholders. We have used this data to generate several recommendations as to how philosophers might increase their broader impacts and what types of changes may be needed at institutional and disciplinary levels. We hope others find these strategies useful and that our study can serve as a model for assessing the broader impacts of philosophy in the future.

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[23] Indeed, as mentioned above, that is precisely the next stage of our research project, which focuses on ways of increasing knowledge flow between philosophy and STEM fields.

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