Changing Debates and Shifting Landscapes in Science Studies: Exploring How Graduate Students with Varied Backgrounds Think About the Role of Value-Judgments in Science

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Abstract

Few studies consider how changes in science studies education might reduce barriers to fruitful engagement with scientific practices. This paper is co-authored by the participants and instructor of a small interdisciplinary graduate seminar at the University of British Columbia (UBC) in Vancouver, Canada. The seminar reflected on the role of value-judgments in science, considering the learning experiences of a science studies student (AR, first author) and four students (of a total of six students registered in the seminar) who have backgrounds in the sciences (JA, GG, BHW, SL), their responses to course materials, and outlines lessons learned with respect to interdisciplinary communication. AR was surprised to find that the science students enjoyed reading and engaging with science studies texts as she thought they would be apprehensive about the epistemic content, but they thought the texts effectively illustrated that science is influenced by social factors. Instead of expressing concerns about epistemic issues, the science students' critiques pertained to the length of texts and writing style. They also felt that some texts "unfairly" attacked scientists, and could be "dry," "abstract," and overly "problem-focused" without offering concrete solutions. This study suggests that interventions which explicitly encourage conversation and collaboration between students in science studies and the sciences more broadly can play a crucial role in dismantling unknowingly held simplistic views of other disciplines. It also speaks to the critical necessity of broad interdisciplinary scholarship which explicitly includes both the natural sciences and humanities. AR noted

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she initially believed that science students would react negatively to outsiders' critiques of the sciences and concluded that science studies education ought to include meaningful engagement with practicing scientists, which is rarely the case. This study illustrates the importance of using texts which have a style and vocabulary not felt as disparaging towards scientists when introducing science students or researchers to concepts in science studies. It also points to the need for studies investigating how students from different research backgrounds may learn to "see" their use of jargon and the implicit assumptions they make about their listeners' familiarity or understanding of a specific idea.

Keywords

engaged science studies; science education; science wars; interdisciplinary collaboration; graduate students; pedagogy

Introduction: Tensions Between Scientists and Science Studies Scholars

In light of recent concerns about the growing and alarming tide of misinformation and public distrust in science, publications like Nature (2020), The Lancet (2020) and Scientific American (2020) have vocalized their concerns about populist politicians undermining science and scientific institutions and acknowledge they must work harder to communicate and build bridges with the public. There are reasons to believe these efforts are undermined by the way science is taught and communicated—as a deliverer of irrefutable facts rather than a deliberative process (Öberg and Campbell 2019). Meira Levinson and Miriam Solomon (2021) point out that normalizing scientific disagreement (while distinguishing it from science denialism) and having discussions about the social and epistemological institutions and processes by which scientific inquiry proceeds gives students a richer set of resources for evaluating competing claims to knowledge. Some American universities have responded to these concerns by creating courses and programs which explicitly set out to strengthen science and technology students' understanding of the degree to which science is dependent on context and embedded in our sociocultural landscape, as well as bringing science studies students into direct contact and conversation with students, researchers, and faculty in the sciences (see Ramachandran et al. 2022d).

A major challenge in this context is the widespread distrust among scientists about claims made by science studies scholars. This complicates efforts to strengthen scientists' awareness of the context dependence of knowledge and other epistemic questions that impact the perception and execution of science. The physicist Richard Feynman, for instance, was famously remembered to have remarked that the "philosophy of science is about as useful to scientists as ornithology is to birds" (Jones 2015). Scientists have also taken issue with the way scientific practice is discussed as a social activity (Weinberg 1994; Wolpert 1994; Labinger 1995). Much more recently, Lucie Laplane et al. (2019) have argued that present-day scientists perceive the philosophy of science as completely different from and antagonistic to science.

Discussions about strengthening scientists' epistemological knowledge commonly rely on a unidirectional, linear model where concepts and ideas from science studies are transferred—unchanged—to the sciences, and focus on challenges related to the addition or integration of science studies content into science (as for example discussed by Bernstein et al. 2017; Fisher 2019). Few endeavors consider how changes in the practice and teaching of science studies might also productively contribute to reducing the barriers to fruitful engagement between science studies and scientific practices. The challenge is often framed as one

of designing courses (focusing on content or structure) that enable or encourage reflexivity solely within science/engineering. For example, several recent efforts by science studies scholars to integrate elements of the social sciences and humanities into undergraduate STEM curricula describe teaching students about the sociocultural, economic, and political contexts of science and technology and encouraging them to propose multifaceted solutions which take these contexts into consideration (Nieusma 2015; York 2018; Tomblin and Mogul 2020). Some notable exceptions include the University of California Santa Cruz's "Science & Justice Training Program," which does not aim to "turn scientists into social scientists or humanities scholars or vice versa" (Lasnier 2013), but rather to encourage ongoing contact, conversation, and collaboration between graduate students and faculty members in the sciences and humanities on issues of ethics and justice in biomedical innovation, species extinction, toxic ecologies, and healthcare reform among other areas (Mary 2016; Reardon et al. 2015). The University of California Davis's "Asking Different Questions: Interdisciplinary Approaches to Science" program similarly brings together students and faculty in the humanities, social, and natural sciences together to identify challenges in STEM graduate training that feminist training may help address.

There seems to be a growing interest in the intersection between practicing scientists and those who study scientific practice, the points of disconnect between them and the common ground they may share. Recently, Plaisance et al. surveyed and interviewed several philosophers of science about the applied impact of their work in science-related domains outside academic philosophy, and their interest in collaborating on research projects with scientists (Fehr and Plaisance 2010; Plaisance et al. 2019; Plaisance, Michaud, and McLevey 2021; Plaisance and Elliott 2021). They found that increasingly, many philosophers of science highly value having practical impacts on science research, policy, education, and society more broadly, and consider such work to be an essential part of the discipline. Even so, it is noticeable that few studies consider how changes in the practice and education of science studies might be one potentially productive approach to reducing the barriers to fruitful engagement between science studies and scientific practices. In this paper, we attempt to take this line of inquiry forward, describing some of our efforts to stimulate conversation between graduate students in an interdisciplinary seminar and discuss the potential implications of these experiences for researchers, educators and students in the sciences and science studies.

This paper focuses on one initiative at the University of British Columbia (UBC) Canada—an interdisciplinary graduate seminar titled "Expertise under fire: Navigating the divide between scientific practice and science and science studies." The course, which was launched in 2019, was created and taught by GÖ (the last author of this paper) and focuses on the role of value-judgments in science. The selection of texts was informed by GÖ's 30-year experience leading interdisciplinary research projects and developing science courses with epistemological content (Öberg 2009, 2011; Öberg and Campbell 2019; Öberg et al. 2022). In contrast to most other initiatives, the seminar targeted graduate students that conduct studies in the natural sciences as well as graduate students who study scientific practices:

> For science students, the aim of this course is to grapple with the role of value-judgments in science and how it plays out in their own field of research. For humanities students studying the scientific enterprise, the aim is to grapple with the communication barrier between science studies and the scientific practice. (course curriculum)

Five of the authors attended the seminar as students in 2020, and GÖ was the course instructor. This paper is based on the first author's (AR) term paper, which was revised in dialogue with the other four students. AR's background is in the humanities and interdisciplinary health science, while the other four co-authors have backgrounds in the natural sciences (see table 1 and Ramachandran et al. 2022d).

Table 1. Academic backgrounds and current areas of study of participants

Name	Academic Background	Current Area of Study	Level of Study
BHW	Interdisciplinary Science	Psychology, Interdisciplinary Environmental Science	MSc
GG	Chemistry	Interdisciplinary Environmental Science	MSc
JA	Engineering, Ecotoxicology	Interdisciplinary Environmental Science	PhD
SL	Liberal Arts, Geology	Geology	MSc
AR	Interdisciplinary Health Science, History	Science and Technology Studies (STS), History	PhD

Considering the Views of Graduate Students

Like Siu Ling Wong and Derek Hodson (2009, 2010, 2014), who appreciate that science studies has contributed much in the way of demonstrating how society and culture shape scientific practice and recognize the importance of "reflective critical comments from practicing scientists" (ibid. 2010, 1434), this paper takes a step in the direction of bringing graduate students with backgrounds in science and science studies into conversation. It builds off previous work by GÖ—her experiences include looking closely at how graduate students teaching assistants and science instructors understand and incorporate ideas from science studies into undergraduate teaching (Öberg and Campbell 2019; Öberg et al. 2022). Graduate education represents a unique moment when students go from primarily being consumers to co-producers of knowledge. Moreover, given that they are undertaking research of their own, graduate students are often working with the newest ideas, models, data, and technologies. It is therefore likely that their views (at least within their own area) of scientific research align with the thought styles of their disciplines.

Using the graduate seminar as a case-study, this paper explores three core research questions:

1. How do the graduate students enrolled in the seminar think about the role of value judgments and expertise in science?
2. What are their reactions and responses to course readings and discussions that focus on these concepts?
3. What are the lessons learned with respect to the communication barrier between science studies and scientific practice?

Methodology for Engaging Interdisciplinary Participation

Case-studies are particularly useful for conducting in-depth exploration from multiple perspectives of a bounded system like an academic course or seminar (Creswell 2013; Simons 2009). The highly detailed and context-dependent knowledge produced during case-study research is vital to gaining a more holistic understanding of participants' views of the role and meaning of values and expertise in science (Flyvbjerg 2006).

AR conducted a) two in-depth, semi-structured interviews with students in the course who had academic backgrounds in the sciences and b) a third follow-up interview with one of the participants to further delve into unresolved issues and lingering questions (see interview schedule in Ramachandran et al. 2022b). The first round of interviews was conducted mid-way through the semester in October 2020 and focused on the participants' experiences in the course and their perception of the readings and concepts that were introduced in class. The second round was carried out in January 2021, after the course ended and focused on their experiences researching and writing their final assignment, which involved writing a case-study about "values in science" within their research areas or disciplines, as well as their takeaways from the course and plans to continue engaging with science studies concepts and literature (see table 3 in Ramachandran et al. 2022c). The final assignment involved the participants writing a case-study about the role and impact of value-judgments in an area of scientific interest to them. They were encouraged to explicitly relate course concepts, readings, and discussions to their study topic. AR's case study, on which the current paper is based, examined the communication barriers between the sciences and science studies. AR interviewed one of the participants, SL, a third time to follow up on unresolved queries from the first two interviews. All participants provided written informed consent prior to the first interviews.[1]

After the course, AR and the instructor (GÖ) agreed that it would be worthwhile revising the term-paper to a manuscript. AR invited the study-participants and the course-instructor to read, comment on, and discuss a first draft of the manuscript. They all agreed to do this, and AR incorporated their feedback and revisions into a second draft which she sent back to them to review. The comments from this second draft were also incorporated into the manuscript. The participants also agreed to participate in the editing process

[1]The ethics application for this study was submitted and approved during the first half of the semester (September-October 2020) that the seminar was taking place (September-December 2020). The participants were then sent an initial letter outlining the study, and if they chose to participate, they could provide their consent during the semester and after the ethics application was approved. The first author anonymized (e.g., using pseudonyms like student one, student two) the comments of all students and only submitted a final draft of her term paper (outlining the data in this study) once all the other students' final grades had been submitted. There were six students in the class overall (including AR), and all six agreed to be interviewed. However, after conducting the first round of interviews, AR made the decision not to follow up again with one of the students, who was unable to directly address any of the questions pertaining to the role of values in science or scientific expertise. The data from this interview was not used in this paper.

and were invited to be co-authors of the paper.[2] AR and GÖ iteratively reviewed and revised the manuscript leading to AR interviewing GÖ about the background and her reasons for creating the seminar and GÖ interviewing AR about her perception and take-homes from the course. These interviews were recorded and transcribed by AR. The revised manuscript was again circulated among all co-authors, followed by an online meeting where the feedback and revision suggestions were discussed. A final version was prepared, agreed upon and submitted for publication. AR conducted a thematic analysis of the interview results, which entailed listening to and transcribing the interviews, reading, and rereading them, and grouping portions of the interview text into categories based on their similar substantive content (Braun and Clarke 2006; Seale 2009). This analytical approach to the interviews was particularly useful because thematic analysis is not anchored in a particular theoretical tradition and can thus be flexibly applied across ontological and epistemological positions.

Rationale for the Seminar

The graduate seminar emerged out of GÖ's previous experiences teaching and revising a first-year undergraduate science course at UBC to include more teaching material illustrating the tentativeness of scientific knowledge, and its socio-cultural embeddedness (Öberg and Campbell 2019). In her interview, GÖ described how many of the scientists teaching the course were very resistant to the inclusion of what they described as "fluffy" philosophical literature, despite wanting students to reflect on the social aspects of science and being open to discussing such issues themselves. These reactions were reminiscent of the message in Hodson and Wong's research—scientists were often very interested in reflecting on the "value-ladenness" and context dependence of science, but responded negatively to scholarship they perceived as jargon-laden, "esoteric" or "inaccessible" (Hodson and Wong 2014; Wong and Hodson 2009, 2010).

> I've often felt this stress of . . . not getting people from the humanities to understand why they need to stop being so . . . jargony, and what it is that is felt as jargon . . . (GÖ)

Given these and other experiences working alongside scholars from the natural and social sciences, and the humanities putting together other interdisciplinary university courses and research projects, GÖ began to conceptualize and organize a graduate seminar bringing science and science studies students together to read texts and have discussions pertaining to the role of value-judgments in science and its context dependence. The focus on "value-judgments" was shaped by GÖ's growing sense that the perception of science as a value-free enterprise as a central reason for the urgent calls to strengthen scientists' epistemic knowledge as well as one of the central ideas from science studies of direct relevance to science students' research practices.

[2] Neither AR, nor any of the other co-authors were financially remunerated for their involvement in this study. They were already aware of this ahead of time and agreed to be involved in writing up and editing this paper knowing this.

The class met weekly for three hours, with half the time spent on discussing the week's readings and the other half developing case-studies. Students presented case-study drafts to each other and provided each other with feedback. At the end, students gave oral presentations of their case-studies and responded to questions from the class. The course began with a short reflection about the participant's perception of what is "real" inspired by an exercise developed by Ragnar Fjelland (2021), followed by a revised version of William Cobern and Cathleen Loving's card-game (1998; Mouat et al. 2018). In this game, students trade cards with claims about science, focusing on the tentativeness of science, the limits of scientific knowledge, the role of evidence, and the context dependence of science.[3] Students then read case-studies in "The Golem" (Collins and Pinch 2012), identified claims that they felt were relevant to their case and presented it to the class. After these introductory case-based exercises, students read, presented, and discussed the role of dissent in science, how to handle normatively inappropriate dissent, and other topics related to the role of value-judgments in science (see table 2 in Ramachandran et al. 2022c).

GÖ selected literature which, she thought, would stimulate discussions between the science and science studies students without being too impenetrable to read for the science students or too banal for the science studies students. Based on previous experiences, she thought Ludwik Fleck's notion of "thought styles" (1979) would be a simple and intuitive way to introduce the social embeddedness of science and she selected this reading as one of the core texts.

> You can get people on board quickly [in reference to thought styles] . . . because . . . wrapping your head around a paradigm [Kuhn] is kind of . . . you can get hours of conversation about 'what is a paradigm?', but when you say we have different thought styles, people go "yeah!" (GÖ)

Having successfully presented and discussed Kevin C. Elliott, Heather E. Douglas, Inmaculada de Melo Martín and Kristen Intemann, Sheila Jasanoff, and Donald A. Schön's work in earlier seminars with science students and active scientists, she included them in the course reading list. Elliott (2017) and Douglas (2009) were selected as they show, in a straightforward manner, that the value-free ideal in science is unrealistic, and that value judgments regularly make up an integral part of scientific practice. De Melo-Martín and Intemann (2018) was selected to support discussions of the central roles of dissent and consensus in science. Jasanoff (2003) was selected to support discussions about scientific hubris, and Schön (1993) to facilitate reflections on the role of language in the production of knowledge.

Engaging Participants as Co-Authors

Sara Doody (2021) has described how collaborative and/or interdisciplinary writing can be particularly fraught with tensions because of a need to negotiate distinct disciplinary approaches to writing research. AR had previously taken some graduate courses in different areas of science studies—encountering texts from the history and philosophy of science and science education, as well as anthropology, sociology, and English

[3] Examples of claims include "Only science can tell us what is really true about the world," and "The predominance of Western scholars in the sciences biases the choice and definition of questions."

literature. While she had not directly encountered any of the course materials selected by GÖ, she was familiar with the themes discussed in the course. The prospect of interacting with the science students about science studies proved to be the most challenging aspect of deciding to take the course, one that caused AR a great deal of nervousness and trepidation at the outset but quickly diminished after her first few interactions with the other students.

> They [the other students in the seminar] were not . . . mean stereotypical scientists who don't want to listen to the criticism of anybody who is not in the sciences . . . I think I may have primed myself to think a little bit in a binary and what surprised me was the multitude of perspectives and the realization that nobody was going to wage some war on relativism the way . . . I sort of expected would happen. (AR)

This sentiment has been previously iterated in another form by Jenny Reardon et al., who describe how, in UCSC's Science & Justice Training Program (previously described in the introduction), students and faculty members' "unknowingly held caricatured views of other disciplines" were the "most common cause of conflict" (Reardon et al. 2015, 18). They note that despite the intentions and desire to produce collaborative work, it is "challenging to adequately understand and generously engage with another discipline's methods and histories" (ibid.).

For AR and her participants, different writing practices—reflective of their various disciplinary traditions—clashed and concerns about how to organize the interview data or deciding on what should or shouldn't be included in an academic paper cropped up throughout the editing process. One example of such a conflict came up after the first round of revisions from the participants. AR originally envisioned a narrative format for the results describing each participant's individual "journey," because she wanted to preserve the details from each interview which, in her mind, told four very different but equally interesting stories of science students with distinct motivations and learning outcomes. She quickly realized that her participants (and co-authors) preferred the results to be presented in a more conventional results section, where quotes from the interviews were organized into several sections and subthemes. They insisted on the creation of a figure outlining each subsection and theme, which would make the results clearer and easier to understand and present the "bigger picture" by showing how they fit together (see figure 1). AR was initially opposed to sacrificing a narrative approach—she thought it important to communicate the subjectivities of the interviewing and writing process. Organizing the results into a figure could, in her mind, portray them in a rigid, non-negotiable manner or even mistakenly attribute an objectivity or finality to the findings that she wished to avoid. While the other students thought a figure would render research results more "readable" and provide a visually appealing way to make sense of otherwise extremely wide-ranging and divergent observations by organizing them into a handful of interrelated themes, developing it was not a neutral activity. AR had to make several decisions about what to include or remove from the results and draw connections between them post-facto in a manner she previously hadn't considered necessary (figure 1). Through this process, however, she realized the potential usefulness of providing readers with a clear set of actionable "take-aways" from reading the paper. She also gained useful insight into how the participants' (and her own) training and research experiences had profoundly shaped their views around the collection, organization, and presentation of information—even in areas outside of their own direct expertise. The participants' backgrounds likely shaped their reception of many of the readings, and their perception of what counted as "real" scholarship—and most importantly, how these views may, in surprising ways, also

align and complement one another. More than merely "translating jargon and explaining concepts clearly," the process of writing and editing collaboratively involved a great deal of justifying and arguing (Doody 2021). It also alerted AR to the critical importance of "compromises and trade-offs . . . required to achieve a kind of integration that allows for critique and mutual world building" between scientists and science studies scholars (York 2018).

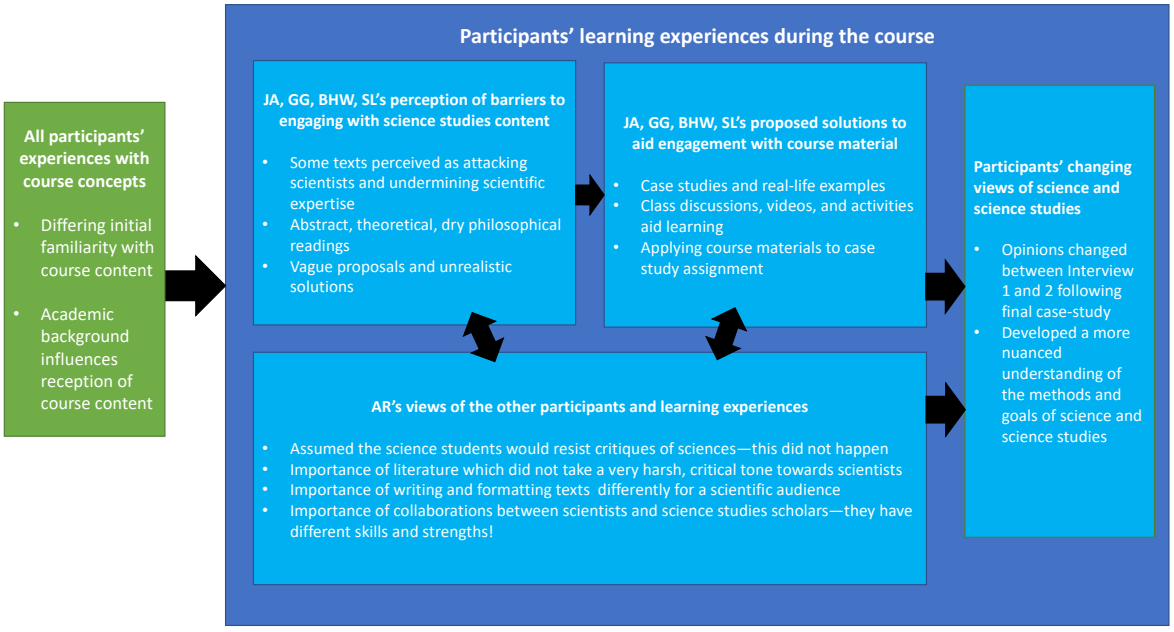

Figure 1. Overview of participants' learning experiences during a seminar targeting graduate students that conduct natural science studies as well as graduate students who study scientific practices (Source: Author's own, 2022).

Participants' Perceived Problems and Barriers with Course Material

Comprehending Attacks on Scientists

All four science students brought up feelings related to scientists being attacked or unfairly blamed by the readings or being expected to shoulder too much of the responsibility for science going "wrong." This view bears a similarity to the spate of negative responses to science studies research penned by scientists like Paul R. Gross and Norman Levitt (1997), Jay A. Labinger (1995; Labinger and Collins 2010) and Lewis Wolpert (1994), as well as by isolated incidents like the Alan Sokal "hoax" in 1996 (Sokal and Bricmont 1997). The results from the interviews indicate, however, that while all the participants claimed to understand why some scientists may have responded poorly to science studies research in the 1990s, they didn't necessarily come to the same conclusions about the usefulness or value of science studies for scientists because of it. For BHW, the issue had to do with undermining scientific knowledge and expertise more broadly. In response to a class assignment where students listened to an episode of "Cited Podcast" focusing on the Science Wars (Katic 2020), she observed:

> [science studies] sometimes come across like [scientists are] writing a fiction and then it's no different from anybody who invents something out of their mind . . . which I think someone who's gone through a very rigorous methodology would find offensive. (BHW)

Reflecting on her discipline, SL suggested:

> My impression of why people, at least in my field, would be skeptical of science studies is that I don't think people really think of geology as having any connection to like social science or social justice or anything like that despite the fact that like a lot of early geologists were eugenicists and geology influences so much about society. Its why things are where they are, but I think people find it easier to consider them totally divorced. (SL)

In contrast to Labinger (1995), who described relativism as an "insurmountable barrier" between science and science studies, none of the participants expressed any serious disagreement with the content of the readings and discussions themselves. However, GG described the readings as having a simplistic view of science and scientists:

> What I think about a lot of the readings of the course is that even though it claims to kind of look at science in society to me it still seems to have quite an idealistic viewpoint in [that] the scientists should act like this and therefore they do act like this, and I don't think that is at all true. (GG)

This view, that science studies scholars do not have a "sufficient detailed understanding" of what science is about because they identify scientific disputes without adequate technical expertise in the disciplines involved and do not flesh out solutions to those problems has been previously described by Labinger (1995).

GG pointed out that course readings like Jasanoff's paper on Technologies of Humility (2003) were ". . . a bit harsh to scientists."[4]

> I can understand where she was coming from by saying you know you need to have humility, you need to be able to accept where you are wrong, you need to accept other people's views . . . but I feel like in the real world that is kind of seen as completely unacceptable, bad for you personally and in your career, not received well and can lead to scientists being scapegoated . . . (GG)

Responding similarly to Jasanoff's paper, JA suggested that assigning responsibility when scientific discoveries or technologies cause problems in society is very complex and involves several stakeholders:

> As much as the experts should be responsible . . . we should also question how much the public should be responsible in the knowledge that they use, the knowledge they consume, how much should the policy makers or decision makers be responsible in interrogating or questioning the integrity of the knowledge and how they implement it. (JA)

[4] See Ramachandran et al. (2022a) for source data (course readings). Jasanoff suggests that governments should reconsider existing relations among decision-makers, experts, and citizens in the management of technology, and recommends policy makers use "humility" when encountering unknown, uncertain, uncontrollable, and ambiguous problems.

JA similarly perceived many of the other readings as critiquing the knowledge production process in science and he initially perceived this as "blaming" and "attacking" them. This shifted, however, when he decided to "relax" and become more "flexible" about challenging his own preconceptions of science.

> . . . it's true scientists are rigid, and I was rigid too . . . most of the papers [in the course] are talking about uncertainties . . . when you're communicating scientific evidence, most scientists including me, don't communicate uncertainties with equal magnitude as the scientific evidence in knowledge production. Therefore, I got flexible to understand that [science studies] is not about attacking scientists but it's about exposing what the uncertainty is all about. (JA)

While AR eventually became more sympathetic to the other students' complaints about the tone of some of the texts, these observations surprised her because she thought that many of the philosophy texts took a measured approach to their discussion of the sciences, providing several examples or case studies to back their claims. Furthermore, she noted that some of the authors—especially Fleck, had educational and professional backgrounds in the natural sciences—she thus viewed their critiques as emerging out of a more than sufficient understanding of the sciences. Moreover, not all the texts focused on scientists alone—Harry M. Collins et al. (2020), for example, also looked at the role of politicians and policy makers in generating public distrust in science.

Speaking Different Science Languages

All four science students also mentioned that the course had far more readings than they were used to and that many of the philosophical readings were quite "abstract," "dry," and "theoretical." For BHW, philosophical texts like Douglas's book on the value free ideal in science tended to be "more dry . . . and kind of the same ideas [kept] popping up again and again."

> I found them dry and repetitive . . . I think having specific examples in a number of disciplines within the text is really helpful instead of it just being broad and abstract. (BHW)

SL and GG similarly found this to be typical of the course, expressing that it was the philosophical terminology that confused or frustrated them, not the concepts or ideas themselves (e.g., the use of specific terms like "teleological" or "tautological" which were not defined, or writing practices like signposting which made texts seem repetitive). This was a point that came up in each of the interviews—while all participants expressed liking the concepts discussed in the readings and at least three out of four of them saw it as applicable to their own research (e.g., thought collectives and thought styles), some of the works, particularly those more philosophically leaning (class readings by Fleck and Douglas came up often during these discussions) were perceived as being "too long," "dry," "jargon-laden," and "wordy."

> The readings being so theoretical . . . made it very difficult for me to understand concepts and . . . contribute to discussions because I really don't feel like I have that level of understanding. (GG)

> I didn't like Fleck so much . . . because it has a lot of complex vocabulary and jargons and I got lost along the way, but I still liked the examples that it gave .(JA)

AR was perplexed by these observations as they diverged from her own experiences engaging with the philosophical readings by Douglas, Elliott, and de Melo Martín and Intemann—which didn't stand out to her as particularly dense. On the contrary, she saw them as quite accessible as compared to texts by other philosophers she had encountered in her training.

> I thought they did a remarkable job of really explaining very well and with a lot of examples these two things [the context dependence and value-ladenness of science] that I would have found difficult to talk about in a coherent, relatable sort of way . . . (AR)

The concerns expressed by the science students are in line with the suggestion made by Gunilla Öberg and Alice Campbell (2019): scientists may respond to "jargon-laden vocabulary" or "abstract" or "philosophical" content with hostility or suspicion. Moreover, all the students (except for AR) were encountering science studies texts for the first time and were unfamiliar with the writing style and content of the humanities. They also point out that interdisciplinary collaboration requires the creation of common ground and common-ground-creation benefits from the development a common vocabulary. The ubiquity and persistence of this theme through both rounds of interviews was a particularly surprising finding for AR who enjoyed reading the philosophical texts during the course and found them to be nuanced and have well thought out arguments which were clearly explained.

Another related point brought up by BHW, SL, and JA during their interviews pertained to scientists and science studies researchers "speaking different languages." They recalled a class activity where students were paired off into groups to read and discuss a paper from one of their fields and look for examples of discipline-specific "generative metaphors" used by the authors (Schön 1993). AR, who was reading a science paper chosen by one of her teammates, brought up that she did not pay much attention to the figures included in the paper, but mostly focused on the text which she assumed was the most important part. This was a matter of great surprise to all the other students, who pointed out that the figures were often one of the most crucial parts of a science paper. They also said they were baffled by the long block-quotes so often used in humanities texts and tended to skip over them altogether.

> I think just considering those small formatting details to get the points across to your audience matters. If you want to teach scientists something, it makes a lot of sense to communicate it in ways they are familiar with. That way any disagreement/confusion can be attributed to the ideas and not their delivery. (BHW)

They suggested having more figures and tables, shorter paragraphs and addressing other formatting or organizational details would make texts seem more readable and diminish the initial resistance to engaging with them.

For AR, the fact that the other students unanimously brought up what she thought of as minor concerns—the authors' writing style or choice of formatting—as a serious impediment to their engagement with science studies stood out to her as an extremely unexpected and important realization.

> These little things, like how something is written, are really not so little and they have lasting consequences . . . scientists aren't just going to engage with science studies with no attempt on our part to try to step away from our own disciplinary jargon to try to make these ideas understandable for people who don't come from the same disciplinary backgrounds. (AR)

This incident was reminiscent of discussions between AR and the other students about creating a figure to describe the results of the present study. This incident, along with others, were reflective of AR and her co-authors' diverse writing and learning traditions, the issues which arose when trying to produce a paper they all agreed represented their views fairly, as well as appreciating the diversity of each other's disciplinary backgrounds and what that brought to the research and writing process.

Benefitting from Collaborative Perspectives

In line with the views above was also the general feeling among participants that the suggestions and solutions from the readings were often not very useful or concrete. This finding is consistent with Öberg and Campbell (2019), whose participants (teaching assistants and university instructors teaching a first-year science course) reacted with "immediate suspicion of 'philosophical' texts and ideas" as potential teaching tools in their courses. Indeed, texts that were highly recommended by the authors' philosophy colleagues as "amazingly good" introductions to science studies were found by the instructors to be overly simplistic and overly critical to the sciences. This perception echoed AR's own experience in the course—where she found that the "philosophical" readings were clearly written, straightforward, and provided useful general solutions to the problems being discussed, other participants in the class perceived them to be repetitive and idealistic. BHW thought the proposals for public engagement put forth in most readings were vague, unhelpful, and difficult to implement.

> . . . a lot of the things they're calling for like having more public participation at all stages of the research process and stuff like that seem like these golden ideas of this ideal world that are so unrealistic. (BHW)

While GG agreed with and was sympathetic to the concepts brought up in class, she described many of the texts as being very "problem-minded" and overly critical and struggled to understand why no solutions had been clearly worked on or implemented.

> . . . you can produce research which proves something or demonstrates useful policy, but you know, there's a gap there [between demonstrating and implementing it] and it's not being taken seriously. (GG)

> I think [science studies scholars] do raise some extremely valid points, but I do still think . . . they are not necessarily thinking about solutions. I do fundamentally . . . have a problem with them just always blaming the scientist . . . there is not a lot of discussion around other actors in it. (GG)

This issue ultimately influenced what GG took away from the course, the overall difficulty of transitioning from research and policy recommendations to more concrete action. Somewhat ironically, it is also the only "problem" brought up by each of the participants without a clear "solution."

For AR, this observation caused her to feel conflicted. On the one hand, she could understand that the science students' previous academic training and disciplinary background might encourage them to focus on identifying and implementing solutions.

> I imagine you do start to feel like . . . "OK there's all these problems . . . but what do I do with it" and that's what nobody ever has an answer for . . . I didn't even notice that . . . talking to them really opened my eyes and I wouldn't have known it otherwise. (AR)

On the other hand, AR felt some of the criticism was unfair—identifying problems in a nuanced multifaceted manner is challenging in itself and laying out fully fleshed solutions is not the primary responsibility of a science studies researcher alone.

> As a [science studies] student my research also involves laying out the problems . . . we are trained to think about issues of theorizing in science, methodology and so on . . . we're not trained to then also come up with and execute a better approach . . . it was something I wanted to defend in some of the interviews, "how can you expect them to have all the solutions, they're not scientists! You are, so you should be contributing!" (AR)

Ultimately, this finding highlighted the importance of need for collaboration between researchers in these disciplines which draw on their respective skills and perspectives.

Reflections on Expanding Discussion

Studies by Vivien Hamilton and Daniel M. Stoebel (2020), Daniel Gamito-Marques (2020), and others have attested to the effectiveness of using historic and contemporary case-studies to contextualize scientific knowledge. All the participants in this study responded similarly, preferring the readings which were based on historical or contemporary examples. GG appreciate the case-studies provided before reading more theoretical texts and recommended including more of them because they gave her a "historical appreciation of how things are done and how things are changing and demonstrating concepts in a real-world manner."

SL and BHW said they found many connections between case-study readings like "The Golem" and what they were encountering in the news. Suggesting that her academic training was a possible reason for this preference, SL ventured:

> It might be because I'm a "hard" scientist or perhaps I'm a "hard" scientist because I have this opinion, but I just have an easier time grasping things when there's a real-life example . . . (SL)

She also pointed out that case-studies "more closely mimic the structure of a scientific paper and so felt more familiar and easier to grab hold of."

BHW similarly thought "[The Golem] was probably one of the most convincing arguments for me of that socially constructed idea [of science] . . ." She would later read the entire book in her own time.

> It would probably be one text from this course that I would recommend to somebody who is not already interested in these topics as something that they might find interesting as a standalone whereas the other books . . . I think you have to be engaged in this kind of a classroom discussion or within a group that is talking about these ideas for them to be as fruitful. (BHW)

While AR was initially surprised at how much the students enjoyed reading the historical and case-study based texts, she later acknowledged that such texts could be useful in initially opening up students' minds to the context dependence and value-ladenness of science.

> I almost feel like if you were to introduce something too theoretical . . . they're writing it from the perspective that their readers already "get it" to some extent. . . . I thought that Douglas and Elliott actually kind of took [the notion of values in science] in a more theoretical direction, but I'm not sure it would have been as effective if they were presented first. (AR)

All the participants mentioned enjoying class discussions, particularly because of everyone's different academic backgrounds coming into the course. SL emphasized that she often found she gained a lot of insight listening to other students' thoughts about the readings. For JA, the course created a platform for students from different backgrounds to come together and discuss common areas of interest. When asked if there were any aspects of the course that stood out to her more than others, GG commented that she wished some of the class discussions had been pushed and expanded on further because they grounded some of the theoretical concepts she otherwise found challenging to fully understand in real-life examples.

> People were talking about either their own experiences or they were talking about how they kind of saw things . . . in their daily lives, media, news etc. . . . I think that made the concepts move from abstract to a lot more real and tangible for me. (GG)

All the participants also pointed out that videos and class activities were particularly successful in explaining and reinforcing topics covered in otherwise "dry" readings. GG mentioned how a card exchange game, which involved groups of students discussing a set of cards containing statements about the nature of science and choosing the ones they agreed or disagreed with, was a "really good conversation starter." She said this was because it forced her to think about ". . . what science actually means and how you interpret that and whether someone else interprets it differently." When readings were accompanied by videos, as was the case for Jasanoff's paper,[5] participants thought they further (and more clearly) explained science studies concepts because the information was presented in a simpler and more accessible format. SL and BHW both mentioned wishing they had watched the video before completing the reading as it would have clarified and provided context for many concepts that were somewhat unclear to them from reading the paper. Allison Marsh and Bethany Johnson (2020) have similarly discussed the effectiveness of using videos, as compared to readings, in encouraging undergraduate students (who are not studying or majoring in history) to become more interested and engaged in studying historical subjects.

AR noted that it was through the regular course discussions and activities that she too became aware of and began to really understand the other students' views about each of the texts and concepts as well as their thoughts about the role of value judgments in science more broadly. They contributed to alleviating her initial discomfort engaging in discussions about science studies with the other students and allowed her to develop a greater understanding of their disciplinary standpoints and a deeper sense of empathy for when their viewpoints diverged.

While the participants' experiences writing this assignment varied, some common themes emerged. All but one brought up being able to engage with particular concepts and texts for a sustained period of time, which facilitated their understanding and interest of science studies more than just reading about them would. For example, GG suggested that this was the first time she was "forced to undertake some kind of

[5] This refers to a YouTube video (Jasanoff 2019) we watched in class of a talk given by the author which discussed the issues covered in "Technologies of Humility" (ibid. 2003).

interdisciplinary research" and put the concepts she had learned in class into practice instead of thinking about them in an abstract way.

> I'm much more of a learner by doing so kind of [being] forced to put it in practice. . . . I'd [known] the concepts, but I didn't really . . . believe them or appreciate them until I was forced to put them in context. (GG)

BHW used the assignment to reflect on her own motivations for selecting certain research topics, questions, and methods, and to reflect on how scientific communities "steer" or "pressure" a researcher's thoughts in directions they may not be aware of.

> I'd always assumed wishful thinking was what you expect out of people with bad motives and conflicting funding . . . but to see it coming out of highly reputable places and researchers that I respect as well as from my own past work was a very interesting finding for me. (BHW)

> Many of the scientific "facts" we know to be "true" are really just concepts that society has accepted and led us to believe, and not ones we have personal firsthand experimental knowledge of. (BHW)

She was now more skeptical of how abstracts were written and would try to consider researcher's motivations while communicating the results of a study "even if they don't have conflicting funding or malicious intent."

SL looked at the interaction between science and policy during the Mount St. Helens eruption, a topic only tangentially connected to her own research. She was learning about the management of risk, an unfamiliar research area for her and found the process of writing without negatively judging how decisions were made about the eruption by policy makers and politicians challenging.

> . . . there were times where I wanted to say that someone had done something wrong and I sort of had to check that impulse because I wasn't there, it's impossible to take the knowledge that I have out of my head and put myself in the headspace that they were in. (SL)

JA described the experience of writing the case-study as a "learning curve" and struggled to write in a manner that was less technical and suitable for the audience (i.e., his classmates).

> The framing of words, phrases and so on must be to an extent where it's not just simple to reduce its meaning but it should be simple to an extent where it can accommodate . . . everybody in the audience. (JA)

This finding was particularly noteworthy in light of his (and other participants') earlier comments that science studies readings tended to be too jargon-laden and having to change his "previous thinking" and move away from his "background training" didn't come easily. JA also mentioned finding it especially challenging to directly apply science studies concepts and arguments to his research, despite understanding and agreeing with the points being made.

For AR, the subject of her case study forms the basis for this paper, but ironically her own views and reflections were virtually absent from the initial drafts. In other words, she believed her role as science studies scholar involved commenting and reflecting on the others, but not to focus on her own journey. The process of conducting the interviews and writing up the findings was especially challenging because AR was

forced to encounter and address her own disciplinary views and biases through the research process. She found it difficult to actively acknowledge, work through, and reflect on her own epistemic standpoint. However, it was a necessary step to understanding and empathizing with the other students' views on specific texts or concepts even when they were in conflict with her own. In fact, it was through the process of drafting and re-drafting this paper, putting words to her own reflections, and incorporating the feedback of the other students into discussions, for example, that she became aware of certain types of disciplinary jargon she was using and how this could prevent potential readers in the sciences from fully appreciating or comprehending the argument she was making (e.g., using terms like "STS," "science wars," "positivism," or "constructivism" but not clearly defining it).

Take-Aways: Appreciating Interdisciplinary Strangification

For AR, some of the most important takeaways from the course came from realizing that so many of the other students' criticisms of the texts discussed in the course had less to do with the concepts or ideas and more to do with their length and the style in which they were written. Indeed, this was a point of consternation for her, since she thought it would be very challenging to organize a science studies seminar without including a variety of readings from different disciplinary perspectives.

> It's disappointing because . . . that's how much you have to read to start to be even sufficiently grounded in anything . . . it can't just happen through short articles and ephemeral discussions in class . . . (AR)

The predilection for specific disciplinary jargon, theoretical/methodological approaches, and writing styles certainly extends to (and prevails in) the sciences—even in those instances where authors have written well outside their usual domain(s) of expertise (as has been the case with numerous recent publications in scientific outlets on equity, diversity, and inclusion in academia or systemic racism or political polarization which cite or draw little from the humanities such as Clyde W. Yancy (2020), Beronda L. Montgomery (2021), and Shannon M. Ruzycki and Sofia B. Ahmed (2022). Taking the time and effort to engage in the "strangification" necessary to both destabilize one's own disciplinary embeddedness and sufficiently familiarize oneself with other disciplines' traditions and approaches seems a critically necessary component of interdisciplinary research (Wallner and Wallner 2002). It also made her reflect on the absurdity that training in science studies often does not require engaging with scientists:

> If the object of your inquiries is science, then the people who do it [science] should be involved in the conversation, in my mind, at a very core level . . . (AR)

Through the course, AR's perspectives about the responsibilities of science studies scholars shifted.

> Until you can have [science studies] programs that recognize, legitimate, and celebrate someone being a researcher who writes specifically for scientists . . . that has to be recognized as its own valid format. (AR)

She described how this experience had influenced her own career trajectory.

> [This course] has opened up research avenues that I really would have never thought were possible and that is . . . like working with people who don't have my expertise or thinking about . . . value judgments or

> context dependence of science, simple things like that, but actually trying to rethink them in a way that is convincing and clear for people who don't share my disciplinary assumptions . . . (AR)

She also expressed some doubt about how much support she would get doing "applied" or "engaged" science studies research and wondered how many opportunities even existed for such research.

> [There is a] difference between having a few people who will, out of the deep desire to actually try to produce that kind of scholarship, do it regardless as opposed to [applied research] being a viable path for any number of science studies students to take up . . . (AR)

She also reflected on the urgent need for interdisciplinary scholars or teams who have the capacity to both lay out the problem and develop solutions—Öberg (2011) has previously described this as essential to being a "reflective doer." Kathryn S. Plaisance (2020) has previously described how philosophers of science are increasingly arguing for and addressing the need to do work that is socially and scientifically engaged. She suggests that some philosophers should develop "interactional expertise" in their scientific arena—the ability to speak the language of a discipline in the absence of an ability to practice (Collins and Evans 2002). This, she suggests, may create opportunities to cultivate trust with scientific communities, improve philosophical work, and facilitate a broader uptake of philosophers' ideas. However, institutional obstacles often hinder the development of such broad interdisciplinary linkages between the sciences and humanities—scholars have pointed, for instance, to the trepidation among graduate students to veer away from conventional pathways for fear of not having a clear disciplinary home or being a suitable candidate for an academic job (Graybill et al. 2006). Others have suggested that promotion and tenure (P&T) requirements may not favor interdisciplinary research efforts (Borrego et al. 2014). In some corners of the humanities for example, single-authored publications may be the gold standard and collaborative work, or non-traditional publications in journals outside the discipline may not "count" or may even be frowned upon by hiring and P&T committees (Huot et al. 2020; Plaisance, Michaud, and McLevey 2021). Lastly, definitions of interdisciplinarity in the sciences rarely extend to the humanities. Nancy Tuana (2013), for example, has highlighted how the National Science Foundation and other large funding institutions have invested significantly in interdisciplinary research, but continue to "under-appreciate" the humanities as a significant interdisciplinary partner, often excluding them altogether.

Concluding Remarks and Future Directions

This study has shed some light on potential areas of contention and barriers to engagement between science studies and the sciences, by focusing on graduate students' experiences engaging with a selection of science studies texts focused on the role of values in science. Overall, the science students stated that reading and engaging with science studies texts had clearly illustrated to them that science is value-laden and deeply influenced by social factors. This was a heartening and surprising finding for AR, who had initially assumed the science students would be more resistant to any critiques of sciences coming from "outsiders." Indeed, her conversations with other science studies students about participating in the seminar provoked reactions similar to the ones she initially had—anxiety, trepidation, even dismissiveness. Interventions which explicitly encourage ongoing conversation and collaboration between students in science studies and the sciences can thus play a crucial role in dismantling those unknowingly holding and simplistic views of other

disciplines. Explicitly revisiting and contextualizing the purported "antagonism" between science studies scholars and scientists during the Science Wars may be a useful way to bring more nuance to any pre-existing beliefs about scientists and the relationship between science studies and the sciences that students may have picked up along the way during their studies.

The science students felt some of the texts "unfairly" attacked scientists and placed too much of the responsibility for change and problem-solving onto them alone. They suggested acknowledging the roles and responsibilities of other stakeholder groups like policymakers and the public. While AR disagreed with this view, noting that some of the authors they had encountered had extensive backgrounds in the sciences themselves, this points to the importance of introducing science students to concepts in science studies using texts which uses a style and vocabulary that is not felt as disparaging towards scientists.

The students also found some of the readings to be overly "dry," "abstract," and exceedingly "problem-focused"—disciplinary jargon was an unexpectedly significant hurdle in facilitating their understanding of and engagement with some of the philosophy texts. AR, who did not initially even see the jargon at all, was very surprised by how vocabulary and stylistic preferences (seemingly minor to her)—like using a figure or block quotes in a piece of writing—could seriously hinder the other students' experiences interacting with an idea or concept. Over the course, she came to see how these texts were read by the others—there was a shift in her own understanding of them, and a realization of the critical importance of writing and formatting differently for a scientific audience. This points to a need for studies investigating how students from different research backgrounds may learn to "see" their use of jargon and the implicit assumptions they make about their listeners' familiarity or understanding of a specific idea.

The science students recommended focusing on texts and other resources which make a special effort to provide historical and contemporary examples illustrating a particular idea or concept. Historical case-studies, class discussions, activities and videos situated the more "philosophical" readings, otherwise thought to be abstract and theoretical, in "real-life." Directly applying course materials to their own research interests also allowed participants to make sense of many concepts or ideas which had otherwise been discussed by science studies researchers in a more general or overarching manner. Having to write an interdisciplinary essay showed most of the participants the ways in which science studies scholarship could complement or even enhance their own research work.

The science students also pointed out that the authors did not suggest concrete solutions to issues they had so clearly outlined. When texts did offer solutions, they were vague and difficult to implement. The science students also described them as having a somewhat "naive" or "idealistic" view of science, and somewhat ironically failing to recognize the particularities of the sciences while critiquing them. This highlights the urgent need for interdisciplinary scholars who are trained to both outline and implement concrete solutions to the problems they identified. This is clearly a deeper issue, as the distance between disciplines are considerable and include styles of both writing and thinking, which cannot be addressed without consistent collaborations between scientists and science studies scholars. This finding also points to a need for science studies programs that not only require students to interact with science and scientists but also offer them the opportunity for more "applied" career paths where they may be able to collaborate or work with students and faculty members in the sciences.

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Data Availability

Data that supports the article by Aishwarya Ramachandran can be accessed in STS Infrastructures at https://n2t.net/ark:/81416/p4g01k.

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