Forthcoming in: Tsou, Jonathan Y., Shaw, Jamie, and Fehr, Carla (eds.), *Values, Pluralism, and Pragmatism: Themes from the Work of Matthew J. Brown*. Boston Studies in the Philosophy and History of Science. Cham: Springer.
Please cite the published version.

Dismantling the deficit model of science communication using Ludwik Fleck's theory of thinking collectives

Victoria Min-Yi Wang

Abstract

Numerous societal issues, from climate change to pandemics, require public engagement with scientific research. Such engagement reveals challenges that can arise when experts communicate with laypeople. One of the most common frameworks for framing these communicative interactions is the deficit model of science communication, which holds that laypeople lack scientific knowledge and/or positive attitudes towards science, and that imparting knowledge will fill knowledge gaps, lead to desirable attitude/behavior changes, and increase trust in science. §1 introduces the deficit model in more detail and shows that adhering to this model often fails to achieve its aims, which motivates the main question of this chapter: how can Ludwik Fleck's theory of thinking collectives address the persistent problem of deficit approaches in science communication? I suggest that it can do so by exposing the deficit model's implicit assumption of an expert-lay divide. Accordingly, §2 lays out Fleck's theory and §3 contrasts it with contemporary debates about science communication. Following this descriptive work, §4 draws on Fleck's ideas to make four concrete suggestions for further questioning the expert-lay divide.

§1. Introducing the deficit model

The classical version of the deficit model of science communication posits that one-way transfer of value-neutral knowledge – in the form of scientific facts – from scientific experts to laypeople will a) fill knowledge gaps, b) lead to desirable attitude/behavior changes, and c) increase trust in science. This *information* deficit model assumes that scientific "facts speak for themselves" (Seethaler et al. 2019, 379) in the sense that "the interpretation of these facts is assumed to be identical for all members of the public" and occurs in a "rational and objective manner" (Simis et al. 2016, 401). The alliance between the value-free ideal of science and

information deficit communication strategies is worth emphasizing since, even if "purely" scientific statements turn out to be value-laden, this is often not recognized and/or acknowledged by the communicators, so that "lay publics are presented with a version of science that is stripped of non-epistemic values" (Branch 2022, 564). It is also noteworthy that most discussions of the information deficit model refer to the communication of research stemming from the natural rather than the social sciences, especially in the anglophone world (cf. Cassidy 2021; Lewis et al. 2023).

Since its inception in the 1960s, the information deficit model has evolved in response to various criticisms.[1] Originally, there was an emphasis on the publics' lack of knowledge of scientific facts[2]; this prompted attempts to increase the publics' scientific literacy, with concomitant surveys to measure this literacy by building on the hitherto more common surveys measuring interest in and attitudes towards science (cf. Miller 1983; 1998). The second wave of science communication in the UK, motivated by The Royal Society's Bodmer report (1985), doubled down on the literacy rhetoric and also focused on the publics' attitudes towards science. Despite generally high levels of interest in science and technology, the report recommended pushing this further and assumed that more scientific knowledge would lead to more positive attitudes towards science.[3] More recently, following the UK House of Lords report (2000) and the COVID-19 pandemic, the trust deficit model has come to the forefront of science communication efforts in an attempt to avoid the pitfalls – outlined in the next paragraph – of pure information deficit models.[4] Given this trust deficit, the reasoning goes, public participation and engagement with science are needed to "re-enchant" publics. However, Martin Bauer, an expert in the public understanding of science, among others (e.g. Wynne 2006; Trench 2008), emphasizes that these different science communication

[1] For the purposes of this chapter, I am focusing on science communication practices in liberal democracies in Western Europe and North America. For developments in this thriving area see Cheng et al. (2008), Jamieson et al. (2017) and Bucchi and Trench (2021).

[2] I use "publics" in the plural to highlight the diversity of this group.

[3] Jon Turney's review (1998), commissioned by the Committee on the Public Understanding of Science (formed as a result of the Bodmer report) summarizes evidence that there is no clear correlation between increased science literacy and positive attitudes towards science, let alone a causal effect; for controversial topics there is no correlation between understanding and attitude. Recent work bolsters this conclusion (e.g. Lackner et al. 2023).

[4] See Goldenberg (2021, especially chapters 1 and 2) for an overview of the development of various deficit models.

discourses do not reflect “a narrative of progress, but one of multiplication of discourses … the latter [discourse] does not entirely supersede the former” (Bauer 2009, 222). Furthermore, scientific literacy is resurfacing as a test for how effective trust-building initiatives, such as citizen juries and science festivals, are (cf. Jensen 2014). For example, a 2017 UK House of Commons report on science communication and engagement acknowledges the recommended move towards two-way engagement laid out in the 2000 House of Lords report, only to state in the next sentence that the “Committee examined in 2013 the public’s *understanding* of the science on climate change, including where people look for science information and how that influences climate change policy” (2017, 5, my italics).

This proliferation of discourses notwithstanding, one enduring critique of information deficit approaches is that they do not achieve their aims. There are many instances in which relaying facts from places of scientific authority to people lacking institutional scientific expertise have been ineffective in changing people’s behavior (and sometimes rightly so). For example, one prominent case report details how (institutionally credentialled) scientific experts tried to impose restrictions on hill sheep farming in Cumbria, England in the wake of the Chernobyl nuclear accident. While mitigating risks from the radiation, farmers however needed to continue to make their livelihoods and felt that “scientists ignored local variations in radioactive fallout effects and … were evidently ignorant of local farming realities and neglected local knowledge” (Wynne 1989, 14). More recent studies show that communicating the cancer risks associated with alcohol consumption can change beliefs but not drinking patterns (Martin et al. 2018; Young et al. 2018), and that relaying information about vaccine safety and efficacy does not necessarily increase vaccine uptake (Kitta and Goldberg 2017; Goldenberg 2021).

Despite efforts to move beyond the information deficit model, newer models that underscore the importance of public participation (e.g., trust deficit models), as well as some scholarly literature on science communication, often still rely on a dichotomy between experts and laypeople. As Michel Callon observes, models of public education and public debate “share a common obsession: that of demarcation. [Both models] deny lay people any competence for participating in the production of the only knowledge of any value: that which warrants the term ‘scientific’” (Callon 1999, 89). Recent work in the UK and USA suggests that many scientists themselves continue to think of science communication as predominantly one-way

communication and education (e.g. Davies 2008; Besley and Nisbet 2013; Dudo and Besley 2016; Choi et al. 2023).[5] For example, a 2014 survey of members of the American Association for the Advancement of Science showed that 84% of the respondents think that the public not knowing much about science is a major problem for science in general, with 40% suggesting that too few scientists communicating their findings is a major reason for this lack of knowledge (Pew Research Center 2015). Thus, although communication specialists know that information deficit models do not work, pressing problems such as the COVID-19 pandemic can lead scientists and policy-makers to think that if "people just had *accurate* information … they would follow science on policies like mask wearing, vaccines, and other policy recommendations" (Scheufele 2022, 299). Despite its well-documented shortcomings, the deficit model is still prevalent, and exemplifies that the dominant way of thinking about knowledge involves a dichotomy between experts and laypeople. The thesis of this chapter is that Ludwik Fleck's concept of "thinking collectives"[6] (1979) and his understanding of science communication (1986c), which have not received enough attention in ongoing discussions of the deficit model, can address the persistent problem of deficit thinking in science communication by a) exposing the assumption of deficit model approaches that there is such an expert-lay divide, and by b) troubling the distinction between experts and laypeople. To do this, I first explicate Fleck's theory of thinking collectives (§2), before exploring how his concepts can be used to describe science communication practices, and how they contrast with contemporary deficit model approaches (§3). Following this analysis, my prescriptive aim is to suggest improvements in science communication by further problematizing the divide between experts and laypeople (§4).

§2. Fleck's theory of thinking collectives and styles

Unlike the relatively strict separation of people into "experts" and "laypeople" – often presumed by scientists and science communicators from the mid-twentieth century until now

[5] Of course, not *all* scientists think of communication with publics as unidirectional; there may well be differences between scientists from different cultures, disciplines and research structures (e.g., universities, pharmaceutical industry, military research etc.).

[6] The published translations of the German *Denkkollektiv* and *Denkstil* are rendered as "thought collective" and "thought style", respectively. However, "thinking collective" and "thinking style" might be more accurate, emphasizing the active nature of these concepts. Fleck himself translated them as "community of thinking" and "style of thinking" (Fleck 1986a, 154). Thanks to Jossi Berkowitz for pointing this out.

– Fleck, writing in the 1930s, describes groups of people, including experts and laypeople, bound together by particular thinking styles as thinking collectives. A collective is defined as "*a community of persons mutually exchanging ideas or maintaining intellectual interaction*" (Fleck 1979, 39). Within such a thinking collective, e.g., the population of Canada in 2020, there are, with respect to any particular topic, so-called esoteric and exoteric circles. The former are comprised of specialists who have gone through an educational process; depending on the topic in question this might mean a graduate degree or an apprenticeship. In the first instance, members of exoteric circles are defined by the absence of "initiation" into a specialty. Generally, esoteric circles are smaller than exoteric circles. For example, during the COVID-19 pandemic there are multiple esoteric circles tackling the pandemic from various angles (e.g., virologists, epidemiologists, public health experts, social scientists, respiratory and critical care doctors and nurses etc.). At the same time there are multiple exoteric circles whose members are more heterogeneous; they include everyone who is not a pandemic expert but also cannot be lumped together into a single "public". For instance, exoteric circles might be loosely characterized by educational, socio-economic status, religious affiliation, voting preferences, urban-rural lifestyles, allegiance to a particular sporting team, whether there are children in a given household, etc. Fleck's description of these circles therefore avoids monolithic depictions of "Science" and the "Public". Importantly, these circles are comprised of individuals who "may belong to several exoteric circles but probably only to a few, if any, esoteric circles" (Fleck 1979, 105). Moreover, the status of circles changes depending on the issue at hand; different people constitute the more expert, esoteric circles pertaining to the climate crisis compared to the COVID-19 pandemic. With respect to questions about greenhouse gas emissions or the efficiency of electric cars, the expert epidemiologist returns, so to speak, to an exoteric circle. According to Fleck, although the composition of these circles changes depending on the subject matter, the intersecting circles are connected because individuals carry thoughts, ideas and moods[7] with them. So, although the epidemiologist is a member of an exoteric circle when it comes to climate change, she brings with her a certain scientifically-informed way of thinking, for example. Simultaneously, as a parent she may have different concerns and thoughts compared to other (exoteric) members who do not have children, but share a mood with other parents in the collective.

[7] More on moods below. It is possible that Fleck was influenced by Heidegger's concept of *Stimmung*, which is now often translated as "attunement". Thanks to Marie-Eve Morin for suggesting this possibility. See also Janik (2006, footnote 11).

Thus, Fleck's model emphasizes the fact that experts have a narrow range of expertise and are therefore laypeople with respect to the vast majority of issues.[8] This stands in contrast with much of the current rhetoric, which pitches experts writ large *versus* laypeople.

Thinking collectives form around so-called thinking styles, which arise out of particular moods that have "two closely connected aspects: readiness both for selective feeling and for correspondingly directed action" (Fleck 1979, 99). Though undoubtedly important in Fleck's philosophy, the concept of mood is a difficult one. Jarnicki (2022) gives a comprehensive overview of Fleck's use of "mood" (*Stimmung* in German, *nastrój* in Polish) and shows how the musical metaphor is not captured by the English word. Importantly, when rendered as "mood" there is a temptation to equate it with a transitory, personal psychological state, whereas the original meaning, Jarnicki argues, is closer to a "social mood" at the interpersonal level. Individuals can become attuned to or achieve a social mood. These moods are thus inculcated in people through "social forces", interactions with others, different types of education, and the surrounding society and culture in general. A thinking style can then be defined as:

> [the readiness for] *directed perception, with corresponding mental and objective assimilation of what has been so perceived*. It is characterized by common features in the problems of interest to a [thinking] collective, by the judgment which the [thinking] collective considers evident, and by the methods which it applies as a means of cognition. The [thinking] style may also be accompanied by a technical and literary style characteristic of the given system of knowledge. (Fleck 1979, 99)

The thinking style of a large thinking collective, such as the population of Canada in 2020, is heterogeneous, defying straightforward characterization, but there might be widespread rejection of practices such as witchcraft, for example.[9] The thinking styles of a collective's

[8] Collins and Evans make a similar point: with respect to a specific technical decision-making process "the wider scientific community *should* be seen as indistinguishable from the citizenry as a whole; the idea that scientists have special authority purely in virtue of their scientific qualifications and training has often been misleading and damaging" (2002, 250).

[9] One might wonder what thinking style and mood hold the population of Canada together as a thinking collective given its heterogeneity e.g., in terms of ethnicities and religious affiliations. This is a valid question to which I return in section §4, but suffice to say that there are coarse-grained common features of thinking collectives. Thanks to Michela Massimi for pressing me on this.

scientific esoteric circles will include things such as particular factual background knowledge and assumptions, know-how regarding scientific instrumentation, as well as following certain communicative conventions. Thinking styles can be more or less stable, with the thinking style of contemporary science being relatively stable. In fact, "as an entity [the thinking collective] is even more stable and consistent than the so-called individual, who always consists of contradictory drives" (Fleck 1979, 44). This stability gives rise to the "intrinsic harmony of [a thinking] style" (Fleck 1979, 87), which induces a certain way of thinking and "looking" at things. Like Thomas Kuhn later, Fleck was influenced by Gestalt psychology. According to him, prevailing social moods influence which gestalt can be perceived, leading to "mood-conforming gestalt-seeing" (Fleck 1979, 179). Changes in mood help to bring about changes in what can be perceived, and seeing a new gestalt can amount to a scientific discovery. The "directed perception" afforded by thinking styles thus often restricts how and what can be thought. However, these styles also enable discoveries when members of the collective work together.

§3. Fleck's science communication & the deficit model

With this outline of Fleck's theory of thinking styles, collectives and their ever-shifting esoteric and exoteric circles in place, we can now examine Fleck's conceptions of communication within such collectives. Depending on the participants and purposes of a conversation, there are three types of intra-collective communication: information exchange, legitimization, and popularization.[10] Regardless of the type of communication, for Fleck the "circulation of thought is always related, in principle, to its transformation" (Fleck 1986c, 85). Even between two people in the same esoteric circle "[t]houghts pass from one individual to another, each time a little transformed, for each individual can attach to them somewhat different associations. Strictly speaking, the receiver never understands the thought exactly in the way that the transmitter intended it to be understood" (Fleck 1979, 42). There is no communication, not even between experts, that does not entail some information gain, loss and/or change, though these changes tend to be larger the bigger the differences in thinking style are.

[10] Fleck also discusses propaganda, which operates between radically different thinking collectives (Fleck 1986c, 85–86). Due to space restrictions and its relevance to modern science communication, I focus only on popularization.

Fleck's notion of popularization – thoughts moving from esoteric to exoteric circles – is most akin to what we call science communication today. He says, "[p]opular science in the strict sense is science for nonexperts, that is, for the large circle of adult, generally educated amateurs" (Fleck 1979, 112). Popularization, especially through science journalism and popular science books, is characterized by the omission of technical details and statements that are contested by experts, thus knowledge becomes "simplified, lucid, and apodictic" (Fleck 1979, 112). Concomitant with this mode of communication are "specific social forces" between members of esoteric and exoteric circles:

> On the one hand it is the specific trust of laymen in the 'initiates' or specialists, and on the other it is the specific dependence of the latter on so-called public opinion and so-called common sense. The effect of both these forces is identical: they strengthen, intensify and carry into effect each thought circulating in the collective. (Fleck 1986c, 102)

Today, some of the science communication literature that has moved on from information deficit models recognizes and discusses exoteric circles' trust deficits at length. For example, Maya Goldenberg stresses that it is frequently not a lack of knowledge that makes parents hesitant to have their children vaccinated, but rather an often-understandable lack of trust (Goldenberg 2021). Given the now-infamous Tuskegee syphilis experiment, she argues, it is no wonder that some Black Americans today harbor mistrust towards governmental and scientific authorities. I do not dispute that a lack of trust in scientific institutions can be problematic, but I want to highlight that Fleck's insight about the two-way relation is often overlooked in today's discourses, with little focus on the ways in which experts also depend on "public opinion and common sense". Scientists and scientific institutions sometimes take for granted that "Science" is owed trust by the publics. For many scientists, this may be partly because of their self-conception as the "thinking" partner to the "feeling" public, where rationality somehow automatically garners trust (Cook, Pieri, and Robbins 2004). Although Fleck does not spell out explicitly what he means by public opinion and common sense, one interpretation is that of values and "moods" held more or less generally in a given thinking collective. Fleck's main case study of the development of the study of syphilis and the eventual discovery of a diagnostic blood test in 1906 can serve as an illustration of this point (Fleck 1979, chapters 1 and 3). By tracing historical notions of diseases, and venereal diseases in particular, Fleck isolates multiple strands of popular thinking that, according to

him, feed into esoteric thinking and practices. In particular, he traces the idea of a blood test for syphilis back to the notion of "noxious, foul mixtures of humors" that, over time, took hold in the popular imagination as a "change in the blood" (Fleck 1979, 11). (The popular metaphor of "bad/foul blood" was still in use during the Tuskegee experiment.) This, in turn, led to several failed attempts at developing a blood test. Fleck suggests that one of the reasons serologists, microbiologists and physicians continued to conduct these unsuccessful experiments was because of the "persistent idea – demanding justification – of change in syphilitic blood" (Fleck 1979, 77). Additionally, he claims that since syphilis was considered a "carnal scourge" in 15th century Europe, and this association of the disease with "punishment for fornication" (Fleck 1979, 41) continued to hold sway in exoteric circles "[t]he attention, importance, and power of development that this research gained from the special moral emphasis on syphilis cannot be overestimated" (Fleck 1979, 77). He contrasts this with a relative lack of research interest in tuberculosis – despite its greater prevalence – because it was viewed as "romantic" rather than "accursed and disgraceful" (Fleck 1979, 77). Fleck refrains from evaluating these exoteric influences on esoteric circles, but uses this example to show how prevailing moods drive certain avenues of research while precluding others.

Moreover, unlike the information deficit model, which holds that "popularization" is the dissemination of facts, Fleck recognizes that popularization is not merely an attempt at informing laypeople, but that the act of popularizing esoteric knowledge also "exert[s] a mental influence" (Fleck 1979, 43) on expert thinking in return. Popular science "furnishes the major portion of every person's knowledge. Even the most specialized expert owes to it many concepts, many comparisons, and even his general viewpoint" (Fleck 1979, 112). For example, he suggests that contemporary (i.e., from the 1920s) histories of syphilis are written in such a way as to obscure the way in which the term "syphilis" changed its meaning over time, and "the general conviction follows that there is no development of thought. This is a conviction that in turn also influences the expert" (Fleck 1979, 116). Fleck also cites examples of specialists importing terminology from their "fund of popular knowledge" (Fleck 1979, 112), such as when economists use the metaphor of an organism to refer to the economy, or when biologists refer to certain cellular arrangement as "cell states". Or as a more contemporary case: when molecular biologists explain to laypeople that DNA is (like) an "instruction manual" for "building" an organism, this popular notion can feed back into the workings of scientists themselves. This can be detrimental if, consequently, molecular biologists adopt reductionist

views of development, potentially precluding cooperation and communication with biologists who hold more holist views (cf. Pigliucci and Boudry 2010).[11]

Fleck also acknowledges the difficulties attendant upon communication when thinking styles are very different. At the extreme he asks us to imagine the exchange between scientists from the 1930s and thinkers from the Middle Ages, “What if we could present our symbols—the potential, or physical constants, or the gene of heredity, etc.—to thinkers of the Middle Ages? Could we expect them to be delighted with the "correctness" of these symbols and instantly listen to reason?” (Fleck 1979, 115). Although the differences in thinking style between members of esoteric and exoteric circles in 21st century Canada are presumably smaller than between the people in his thought experiment, Fleck is pointing out one of the main flaws of information deficit thinking, namely the assumption that simply providing facts is enough for people to “listen to reason”, an assumption that many scientists themselves hold (cf. Simis et al. 2016).

Fleck clearly does recognize knowledge differentials between specialists and members of exoteric circles, but only with respect to suitably well-defined scientific questions. There is no doubt that years of working as a physician or laboratory researcher equip the practicing doctor and scientist with knowledge, know-how and intuitions that laypeople lack.[12] However, Fleck casts a critical eye even on interactions that laypeople would lump together as “expert” interactions. For example, although both bacteriologist and doctor are part of esoteric circles, even they cannot achieve mere information exchange without thought transformation. Accordingly, the bacteriological report “is specially written to suit the general practitioner, but it does not represent the knowledge of the expert. It is vivid, simplified, and apodictic” (Fleck

[11] I agree with an anonymous reviewer that causal claims should be made cautiously: does the simplification during popularization *cause* biologists to adopt reductionist views, or did they already hold these views before? Fleck might respond by suggesting that textbooks, which are used to “initiate” specialists, already contain many popular elements, thus “clos[ing] the circle of intracollective dependence in knowledge” (Fleck 1979, 113). More empirical work may shed light on this question.

[12] It would be a stretch to interpret Fleck as recognizing “lay expertise” or knowledge co-production between “experts” and “laypeople”. However, Fleck’s insistence on the context-dependence of who counts as a member of an esoteric circle suggests that, if scientific questions were reframed to make the societal consequences at stake more explicit, he might assent to the idea that members of exoteric circles could be as well equipped to contribute to inquiries as “experts”. Thanks to Maya Goldenberg for raising this point.

1979, 113). Fleck suggests that the ideal of an informing statement is “merely a certain boundary possibility” that could occur only when the receiver of information has both confidence in the sender’s abilities and the “full possibility of checking the contents” (Fleck 1986c, 86). Otherwise – and this applies to the vast majority of communicative situations even within esoteric circles – one specialist’s “attitude is colored either with an excess of confidence and a lack of the possibility of checking (and thus appears … *to a certain extent as a layman*), or else with an excessive desire of testing” (Fleck 1986c, 87, my italics). Even among esoteric circles there are these two-way relations otherwise associated with popularization. The account thus rightly emphasizes the fact that any individual expert has only a narrow range of expertise. However, because of the trust of laypeople in specialists “the layman has a tendency to overestimate the capabilities of the specialist and to underestimate his limitations” (Fleck 1986c, 102).[13] Additionally, all specialists are laypeople with respect to the vast majority of societally important issues and may underestimate their own limitations outside their expertise.[14] Overall, Fleck’s account makes distinctions between individuals in a collective much blurrier by highlighting the many two-way interactions in which thought transformations take place.

Others have also compared Fleck’s theory with present-day science communication practices (e.g. Bucchi 2008; Bauer 2009; Mößner 2016). Some of these comparisons, however, seem to misconstrue Fleck’s insights regarding the inextricable links between exoteric and esoteric circles. For example, Bauer, after discussing iterations of the deficit model, closes his account with a description of Fleck’s theory.[15] Bauer interprets Fleck as “suggest[ing] an image of concentric spheres of science, similar to a planetary system of a centre and circulating peripheries” (Bauer 2009, 236; Figure 1). The monolithic core of experts in the middle is

[13] Of course, not all laypeople trust experts across the board. For example, the Tuskegee experiment helps explain why Black Americans today distrust scientific institutions more than members of other demographic groups. Moreover, public trust in scientists has fallen since the start of the COVID pandemic in the USA, especially among Republicans, while trust in science has increased in the UK. Fleck’s statements may thus not apply wholesale to the contemporary USA and UK, but despite fluctuating levels of public trust, scientists remain trusted by a majority of people (Fonseca et al. 2023; Pew Research Center 2023).

[14] The phenomenon of experts asserting knowledge in areas outside their expertise has recently received the label “epistemic trespassing” in analytic philosophy (e.g. Ballantyne 2019).

[15] I focus on Bauer’s work here partly because of space constraints and partly because of his prominence in the public understanding of science field.

surrounded by an exoteric circle, which tentatively includes consumers, students, and politics. Based on this visualization, Bauer claims that "the problem of [public understanding of science] research for the future will be to map the esoteric-exoteric distance of the public conversation from science" (2009, 237).

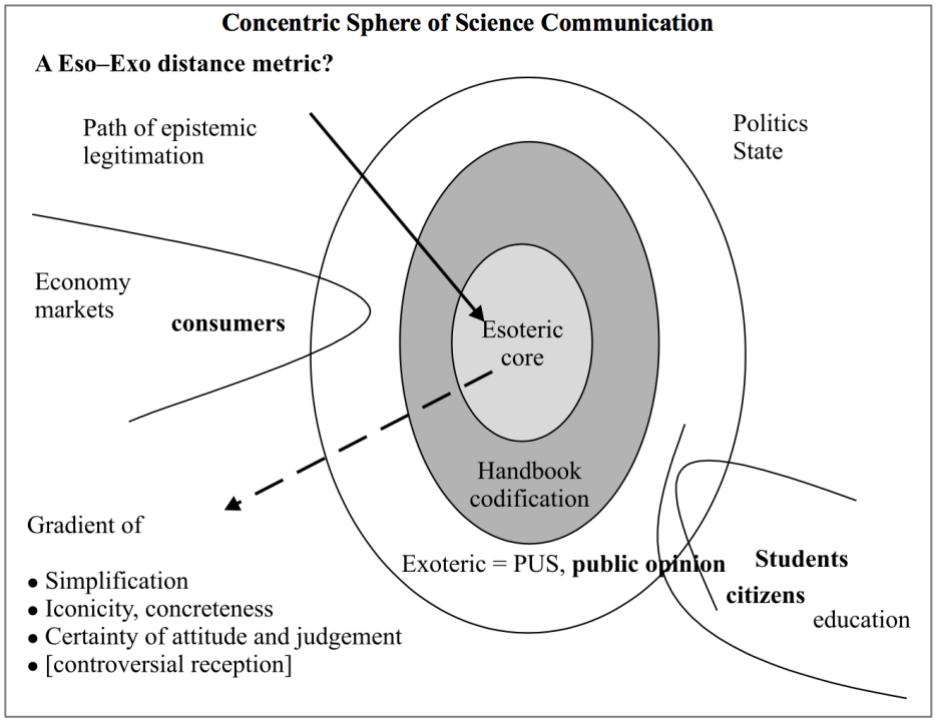

Figure 1. *Bauer's representation of Fleck's ideas about science communication. PUS = public understanding of science. Copied from Bauer (2009).*

However, I believe this interpretation mistakenly reifies the expert-lay dichotomy and misinterprets Fleck, who is clear that thinking collectives consist of "many such mutually *intersecting* esoteric and exoteric circles" (Fleck 1986c, 101, my italics). We are invited to imagine the above diagram much more like a complex Venn diagram, in which members of each circle shift when different questions arise in the collective. Aren't all experts also always consumers and at least residents of a country? In Figure 2 I sketch a diagram, which hints at the diversity of esoteric and exoteric circles, their interconnectedness, and how members of each shift with respect to two different societal questions. On the left, the "pink thinking collective" is grappling with the COVID-19 pandemic: the dashed pink circles represent esoteric circles and the pink crosses represent individuals who count as experts with respect

to the pandemic, including virologists and epidemiologists[16]. On the right, the *same* thinking collective is addressing the climate crisis: the "pink experts" now no longer belong to the relevant esoteric circles, although they need not lose their scientifically-informed way of thinking (their "scientific mood"). Instead, "blue individuals" are the experts – e.g., meteorologists, public policy makers – with respect to climate change. Of course, this diagram is simplified; I am not, for example, claiming that virologists cannot be basketball fans. Moreover, given the socio-political structure of "Western" thinking collectives, it would be plausible to equate the rectangles delimiting the collective with consumer society. To avoid cluttering the diagram, I have also not included concentric esoteric circles to represent the "various *degrees* of initiation and numerous links between them" (Fleck 1986c, 102), which would distinguish between, for example, experts on the coat proteins of coronaviruses versus virologists more broadly. Finally, although only esoteric circles are represented with dashed lines – indicating the porosity of these circles to the moods of the collective – exoteric circles are also porous to moods. Despite these simplifications I believe this representation more accurately captures Fleck's intentions. Unlike Bauer, who wants to measure the distance between esoteric and exoteric circles, the figure below highlights that distance might not be the problem. Rather, the focus should be on studying the solidity or porousness of these circles; I expand on the porousness metaphor in the next section. Taken together, Fleck's theory successfully problematizes the distinction between experts and laypeople, and also shows how members of a thinking collective are bound to each other by pervasive moods.

[16] Thank you to an anonymous reviewer for alerting me to my own biases as a natural scientist: there is certainly also a need for considering esoteric circles of social scientists during a pandemic (e.g. Lohse and Canali 2021; Pickersgill and Smith 2021).

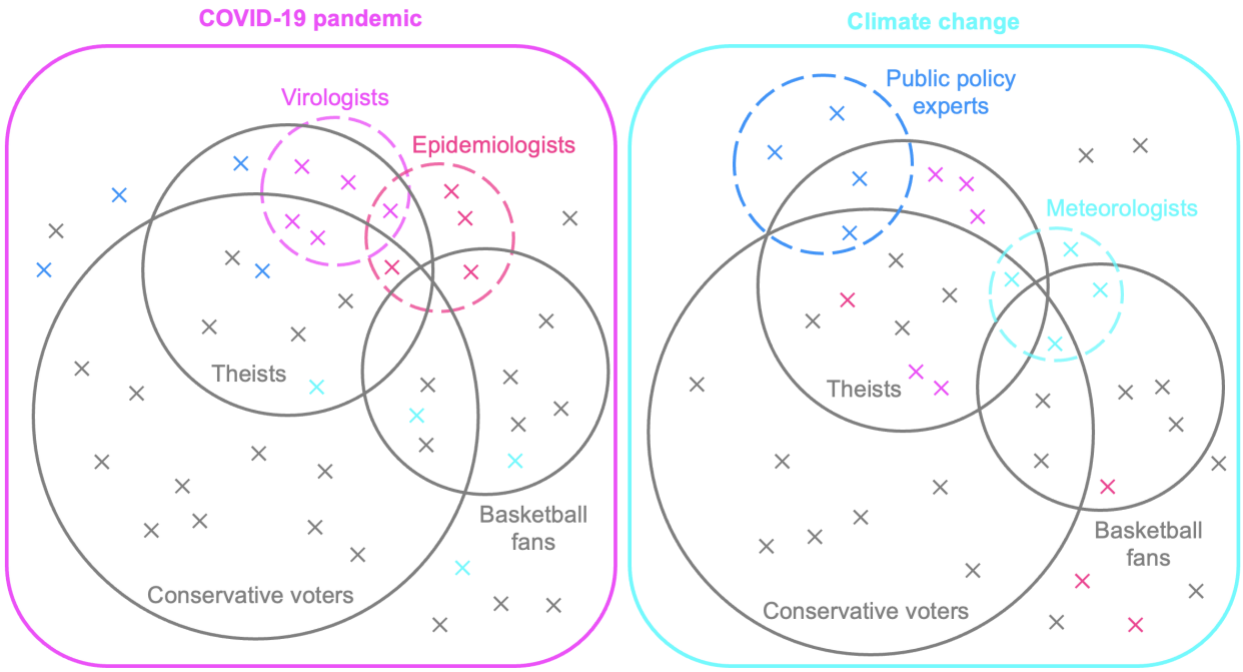

Figure 2. *Fleck's intersecting esoteric and exoteric circles. Left: thinking collective addresses the COVID-19 pandemic; right: same collective addresses climate change. Each* X *represents an individual. Circles represent a limited number of esoteric (colored) and exoteric (grey) circles.*

§4. Making the expert-lay divide more porous

Before making suggestions for how to understand the porousness of the boundaries between experts and laypeople, and how this porousness could be fostered, I address a worry a critic might have regarding Fleck's concept of thinking collectives, namely that it is too loose or amorphous. If some of the examples above were confusing this might be because "we could agree with anybody who calls the [thinking] collective fictitious" (Fleck 1979, 44). Although it plays such a central role for Fleck, the concept of a thinking collective is ambiguous. At times collectives are large and disparate, held together by "Christian ideas" (Fleck 1986c, 86). At other times, thinking collectives exist when "two or more people are actually exchanging thoughts … A special mood arises" (Fleck 1979, 44). This ambiguity can cause confusion, but if we remember that collectives are characterized by certain moods and thinking styles, and that esoteric/exoteric circles are defined with respect to a particular question, then it becomes clear that Fleck does not intend his descriptions to have some metaphysical or ontological grounding. Thinking collectives are pragmatic constructs, and Fleck remains aware of this fact. As we will see below, this distinguishes him from others who are involved

in constructing boundaries and drawing distinctions, but do so without this critical awareness. For contemporary discussions of science communication, it might, by turns, be useful to apply the "fictitious" concept of a thinking collective to a population's subsections that have been historically marginalized, or to certain nation states when the questions concern a specific country, or the European Union when questions are of bloc-wide interest. At other times it can be productive to attribute certain thinking styles, and their "literary styles", to particular academic subdisciplines addressing similar research questions in different ways.[17] In sum, a thinking collective is "not to be understood as a fixed group or social class. It is functional … rather than substantial" (Fleck 1979, 102). Nonetheless, Fleck's theory fruitfully problematizes the expert-lay divide. How do we take the idea of thinking collectives seriously *as constructs*? How else can we question the expert-lay dichotomy? How can the boundaries between esoteric and exoteric circles be made porous?

The clearest answer Fleck gives to the question of porousness between esoteric and exoteric circles is the idea of two-way dependence between these circles. Above I explicated the proposal that popularization, popular knowledge and thinking styles (tacitly) influence the thinking and acting of experts. Given that eliminating thought transformations is impossible, what would promote transformations that foster genuine two-way communication? As the communications scholar Dietram Scheufele notes, "every single issue emerging at the science–society interface is at least *partially* a science communication challenge" (Scheufele 2022, 298). Exactly how to manage thought transformations will be context-dependent, but important components might include communicating uncertainties surrounding scientific findings and highlighting that the fact/value distinction is frequently artificial. However, I want to resist the temptation – which Scheufele yields to by referring to the binary "science-society interface" – of presupposing a stable separation between experts and laypeople. As the philosopher Matthew Sample points out, the imaginaries of philosophers of science influence how they theorize about science and society, affecting both their descriptions of and prescriptions for communicative practices. When philosophers presuppose or idealize a particular science-society interface, their theories will yield certain conclusions while precluding others. At the very least, these theorists ought to hold themselves responsible for their imaginaries (Sample 2022). With these points in mind, I turn to making four suggestions

[17] Think, for example, of the different literary and thinking styles associated with philosophy of science and science and technology studies.

for making the expert-lay divide more porous, and although these suggestions have largely been made before, here I use Fleck's conceptual resources in the context of science communication to provide new additional justification for them.

§4.1 Esoteric diversity

First, we ought to increase the diversity of scientific experts by drawing on many more and different exoteric circles. This point has been argued by many feminist philosophers of science, but maybe most prominently by Helen Longino. For her, the goal of diversity is to increase objectivity and improve scientific knowledge production. Accordingly, "the exclusion of women and members of certain racial minorities from … scientific professions constitutes not only a social injustice but a cognitive failing" (Longino 2002, 132). More recently, Goldenberg advocates for increased diversity among scientific experts so that trust deficits between experts and lay communities can be repaired, claiming that "the publics need more than academic credentials. They need some assurance that the experts understand their values" (Goldenberg 2021, 55). So, although this idea is not new, Fleck's framework provides a different rationale for the purposes of science communication. Instead of drawing from a limited number of exoteric circles, research ought to be conducted by people who represent a wider variety and range of "moods" of a thinking collective. Recall that individuals belong to multiple exoteric circles and carry their moods with them when they become experts. One might therefore imagine that diversifying esoteric circles will reduce the barriers for communication between esoteric and exoteric circles, leading, perhaps, to smaller, or at least less distorting, thought transformations. With respect to this first suggestion, then, the porousness metaphor refers to the ability of people to move more easily between different esoteric and exoteric circles.

§4.2 Science journalism

Even if esoteric circles are diversified, not everyone will join an esoteric circle through "initiation" at the graduate level, and those that do are limited in expertise to their particular esoteric circles. A second way to conceptualize and increase the porousness between esoteric and exoteric circles is to promote the role of science journalism as a means to poke holes into the boundaries between experts and laypeople, such that the latter can "see" into the workings of esoteric circles. For Fleck, oversimplified reporting by journalists can lead to

distorting thought transformations. This certainly happens and is a particular worry for science journalism that operates under time pressure or aims at entertainment.

After dismissing this distorting kind of science journalism, Fleck discusses the roles of art critics at some length, which, I argue, can be analogous to those of investigative science journalists. With respect to fine art, Fleck contends that there are two esoteric circles: one comprised of artists and one of art critics. The critics mediate between artists and wider exoteric circles, thus "popularizing" art to some extent. But the critics also influence the artists and have "a specific knowledge of art in which both the artists and the public form the exoteric circle" (Fleck 1986c, 104). Similarly, investigative journalists with time and resources to conduct in-depth reporting can mediate between esoteric and exoteric circles, influencing both.[18] For example, building on critiques of the value-free ideal of science, Kevin Elliott suggests that "[s]cience journalists have valuable opportunities to contribute … by identifying and explaining major value judgments in scientific research … on behalf of non-specialists" (Elliott 2019, 4). This move could help laypeople appreciate that disagreements between experts can arise not because of disagreements about the empirical evidence itself, but also because of interpretive differences, which often, and sometimes tacitly, depend on a variety of (non-epistemic) value judgements. Revealing these value judgements through journalism is distinct from the classical information deficit approach discussed in §1 since laypeople are learning about scientists' decision-making at a different level and not merely acquiring more "scientific facts". Moreover, journalists' reporting on value judgements has the benefit of potentially making these values explicit to scientists themselves. I would add to Elliott's proposal that it might be useful not just to reveal important value judgements at crucial decision-making points, but that some investigative science journalism should report on the "nature of science". That is, journalists could show both that climate scientists disagree about potential mitigating measures because of differences in their risk tolerances, for example, but also that the expertise to create and interpret models of e.g., rising sea levels is spread across a large number of scientists who come from neighboring esoteric circles (e.g., statistics,

[18] Science journalism is underexplored in philosophy of science. Previous work includes Gerken's "justification reporting": in addition to reporting purported facts, "science reporters should, whenever feasible, report aspects of the nature and strength of scientific justification or lack thereof for a reported scientific hypothesis" (Gerken 2020, 95). However, this proposal still follows deficit thinking because justification is given in terms of more information. Figdor (2023) discusses the epistemic virtues of good science reporting.

oceanography). This kind of reporting could also help scientists recognize their interdependence.[19]

§4.3 Science education: K-12

A third, related suggestion for moving beyond the information deficit model is to help laypeople and scientists understand that science is not a monolithic, value-free enterprise of knowledge creation. The idea is to change science education starting in kindergarten (cf. Lederman, Lederman, and Antink 2013; Rudolph 2023). As Heather Douglas says, "[w]hat is *not* needed is a passing grade on fact-based literacy tests. What *is* needed is an understanding of the process and practice of science" (Douglas 2021, 137). Although there is increasing attention to the "nature of science" in school curricula, these still tend to focus on contemporary science, leaving out its history and sociology (Berkovitz 2017). In Fleck's terminology, this education would aim to make members of exoteric circles – especially those that will not join an esoteric circle – more aware of the practices of esoteric circles. Importantly, and this aspect is underemphasized by Douglas, this kind of education should reveal the interconnectedness of esoteric and exoteric circles. This suggestion is similar to the idea of investigative science journalism above, but intended for children passing through the educational system. Importantly, this is likewise not to be thought of as an information deficit approach precisely because the education should go beyond the "scientific facts". Going through such an education will help laypeople come to the "science-society interface" suspecting that this interface is partly constructed, and better equipped to communicate with experts so that there are fewer detrimental thought transformations.

§4.4 Science education: at esoteric initiation

Finally, while the above suggestion seems right, there are two problems with it, one practical, the other conceptual. The practical worry is that overhauling school curricula, (re-)educating teachers, and rolling out this kind of education is time-consuming. If this approach succeeds it will, of course, also affect how experts understand their roles within a thinking collective, since they start their education with everyone else. The conceptual worry is that scientists themselves often create and maintain the boundaries between "science" and "society", which

[19] It might be apt to describe this as a double deficit model since members of both exoteric and esoteric circles can be unaware of these value judgements, and the "nature of science" more broadly. Thanks to Denis Walsh and Rebecca Korf for (separately) pointing this out.

affects how they communicate. When experts are “initiated” into their specialties, the thinking styles of these esoteric circles are often such that members’ exoteric moods are suppressed in favor of the prevailing “scientific mood”. If this is true, then diversifying esoteric circles will not automatically lead to communicative changes. This scientific “boundary-work” has been characterized by the sociologist Thomas Gieryn (1983). He describes how scientists, often through their communication efforts, demarcate the projects, questions, and practices they deem scientific, so that they can keep other actors, including journalists, politicians and other members of the public, separate. Gieryn illustrates this with an example from the Cold War during which the US government tried to control scientific knowledge circulation to prevent the Soviet military from gaining information. In response, the National Academy of Sciences issued a report recommending that the vast majority of scientific knowledge not be restricted, in part because “basic science” should not be censored or held responsible for downstream military uses. In this case, Gieryn contends that boundary-work aims to “protect professional autonomy: public scientists construct a boundary between the production of scientific knowledge and its consumption by non-scientists … The goal is immunity from blame for undesirable consequences of non-scientists' consumption of scientific knowledge” (Gieryn 1983, 789). As mentioned previously, more recent empirical studies of scientists’ predominant attitude towards science communication – as one-way knowledge transfer – suggest that this boundary-work is ongoing (e.g. Cook, Pieri, and Robbins 2004; Davies 2008; Pew Research Center 2015; Dudo and Besley 2016). Therefore, educating people who are becoming members of esoteric circles about the social situatedness of science could raise awareness of this boundary-work. For example, undergraduate and graduate science programs could include compulsory courses in the history, philosophy and sociology of science. Making scientists aware of their social situation, how intricately bound they are to their exoteric circles, and the many ways in which values legitimately enter scientific practice could change how they then communicate science. Fleck recognized that scientists, in part because they “grow out of” exoteric circles, often lack awareness of the workings of science. He says, “[i]t is highly interesting to establish to what extent scientists who devote the whole of their life to the problem of distinguishing illusions from reality are unable to distinguish their own dreams about science from the true form of science” (Fleck 1986b, 113). Sample argues that “we philosophers have the opportunity to hold ourselves to a higher standard [than scientists, policy-makers, and publics], reflecting on our choice of idealization and its relationship (if any)

to messy human practices" (Sample 2022, 13). I see no reason why scientists should not also reflect on and take responsibility for their imaginaries.

§5. Conclusion

Scientists, and experts more generally, are engaged in boundary-work; merely telling them that they are constructing boundaries and thereby closing off avenues of two-way communication will not necessarily disrupt these boundaries. However, Fleck's notion of collective moods could suggest a more productive way forward. According to him, these moods bind people together in a collective, bridging esoteric and exoteric circles. So, to question or undermine the partly constructed boundaries between experts and laypeople we might appeal to shared feelings/affects/emotions, rather than relying only on shared information. In the context of science communication specifically, the science and technology studies scholar Sarah Davies suggests that affect has been under-theorized in work on public engagement, and that we should "become attentive to the role of materialities, affects, and place in encounters between publics and science" (Davies 2014, 98). To be sure, there is no single shared feeling that people rally around to support vaccine or climate change policies. However, it is often affect-laden events or experiences – such as art-science collaborations or protest movements – that prompt people to reflect on their assumptions, values, and practices (e.g. Salmon, Priestley, and Goven 2017).[20] If Fleck is correct in thinking that moods are the basis for holding people together in a collective, then this offers us a different perspective through which to view the expert-lay dichotomy: paying attention to sharing and shared moods may be a step towards making boundaries more porous.[21]

[20] See also Furman (2024) for a discussion of how information/beliefs, values, and emotions interact to shape people's (dis)trust in science and public health.

[21] Thanks to Jossi Berkovitz for feedback and for introducing me to Fleck in his social epistemology seminar. I presented an earlier version of this project at the IHPST in Toronto, the philosophy graduate student conference at the University of Alberta and at the 11th Values in Medicine, Science, and Technology Conference in Dallas; many thanks to participants at those conferences for their feedback, especially: Alison Wylie, Heather Douglas and Holly VandeWall. Thank you to Maya Goldenberg, Joyce Havstad and two anonymous reviewers for their written feedback.

Bibliography

Ballantyne, Nathan. 2019. 'Epistemic Trespassing'. *Mind* 128 (510): 367–95. https://doi.org/10.1093/mind/fzx042.

Bauer, Martin W. 2009. 'The Evolution of Public Understanding of Science—Discourse and Comparative Evidence'. *Science, Technology & Society* 14 (2): 221–40. https://doi.org/10.1177/097172180901400202.

Berkovitz, Joseph. 2017. 'Some Reflections on "Going Beyond the Consensus View" of the Nature of Science in K–12 Science Education'. *Canadian Journal of Science, Mathematics and Technology Education* 17 (1): 37–45. https://doi.org/10.1080/14926156.2016.1271927.

Besley, John C., and Matthew Nisbet. 2013. 'How Scientists View the Public, the Media and the Political Process'. *Public Understanding of Science* 22 (6): 644–59. https://doi.org/10.1177/0963662511418743.

Branch, T. Y. 2022. 'Enhanced Epistemic Trust and the Value-Free Ideal as a Social Indicator of Trust'. *Social Epistemology* 36 (5): 561–75. https://doi.org/10.1080/02691728.2022.2114114.

Bucchi, Massimiano. 2008. 'Of Deficits, Deviations and Dialogues: Theories of Public Communication of Science'. In *Handbook of Public Communication of Science and Technology*, edited by Massimiano Bucchi and Brian Trench, 1st ed., 57–76. Routledge International Handbooks. London: Routledge.

Bucchi, Massimiano, and Brian Trench, eds. 2021. *Routledge Handbook of Public Communication of Science and Technology*. Third edition. Routledge International Handbooks. London: Taylor & Francis.

Callon, Michel. 1999. 'The Role of Lay People in the Production and Dissemination of Scientific Knowledge'. *Science, Technology and Society* 4 (1): 81–94. https://doi.org/10.1177/097172189900400106.

Cassidy, Angela. 2021. 'Communicating the Social Sciences and Humanities: Challenges and Insights for Research Communication'. In *Routledge Handbook of Public Communication of Science and Technology*, edited by Massimiano Bucchi and Brian Trench, Third edition., 198–213. Routledge International Handbooks. London: Taylor & Francis.

Cheng, Donghong, Michel Claessens, Toss Gascoigne, Jenni Metcalfe, Bernard Schiele, and Shunke Shi, eds. 2008. *Communicating Science in Social Contexts: New Models, New Practices*. Dordrecht: Springer Dordrecht. https://doi.org/10.1007/978-1-4020-8598-7_7.

Choi, Sera, Ashley A. Anderson, Shelby Cagle, Marilee Long, and Nicole Kelp. 2023. 'Scientists' Deficit Perception of the Public Impedes Their Behavioral Intentions to Correct Misinformation'. *PLOS ONE* 18 (8): e0287870. https://doi.org/10.1371/journal.pone.0287870.

Collins, H.M., and Robert Evans. 2002. 'The Third Wave of Science Studies: Studies of Expertise and Experience'. *Social Studies of Science* 32 (2): 235–96. https://doi.org/10.1177/0306312702032002003.

Cook, Guy, Elisa Pieri, and Peter T. Robbins. 2004. '"The Scientists Think and the Public Feels": Expert Perceptions of the Discourse of GM Food'. *Discourse & Society* 15 (4): 433–49. https://doi.org/10.1177/0957926504043708.

Davies, Sarah R. 2008. 'Constructing Communication: Talking to Scientists About Talking to the Public'. *Science Communication* 29 (4): 413–34. https://doi.org/10.1177/1075547008316222.

———. 2014. ‘Knowing and Loving: Public Engagement beyond Discourse’. *Science & Technology Studies* 27 (3): 90–110. https://doi.org/10.23987/sts.55316.
Douglas, Heather. 2021. *Science, Values, and Democracy: The 2016 Descartes Lectures*. Edited by Ted Richards. Consortium for Science, Policy & Outcomes, Arizona State University.
Dudo, Anthony, and John C. Besley. 2016. ‘Scientists’ Prioritization of Communication Objectives for Public Engagement’. *PLOS ONE* 11 (2): e0148867. https://doi.org/10.1371/journal.pone.0148867.
Elliott, Kevin C. 2019. ‘Science Journalism, Value Judgments, and the Open Science Movement’. *Frontiers in Communication* 4: 1–10.
Figdor, Carrie. 2023. ‘Science Journalism and Epistemic Virtues in Science Communication: A Defense of Sincerity, Transparency, and Honesty’. *Episteme*, 1–12. https://doi.org/10.1017/epi.2023.38.
Fleck, Ludwik. 1979 [1935]. *Genesis and Development of a Scientific Fact*. Chicago: University of Chicago Press.
———. 1986a [1960]. ‘Crisis in Science’. In *Cognition and Fact: Materials on Ludwik Fleck*, edited by Robert Sonné Cohen and Thomas Schnelle, 153–58. Boston Studies in the Philosophy of Science; v. 87. Dordrecht: D. Reidel Pub. Co.
———. 1986b [1946]. ‘Problems of the Science of Science’. In *Cognition and Fact: Materials on Ludwik Fleck*, edited by Robert Sonné Cohen and Thomas Schnelle, 113–27. Boston Studies in the Philosophy of Science; v. 87. Dordrecht: D. Reidel Pub. Co.
———. 1986c [1936]. ‘The Problem of Epistemology’. In *Cognition and Fact: Materials on Ludwik Fleck*, edited by Robert Sonné Cohen and Thomas Schnelle, 79–112. Boston Studies in the Philosophy of Science; v. 87. Dordrecht: D. Reidel Pub. Co.
Fonseca, Cristina, Alison Woollard, Laurence Hurst, and Jonathan Pettitt. 2023. ‘Covid-19 and the Public Perception of Genetics’. London: The Genetics Society. https://genetics.org.uk/public-perception-of-genetics/.
Furman, Katherine. 2024. ‘Beliefs, Values and Emotions: An Interactive Approach to Distrust in Science’. *Philosophical Psychology* 37 (1): 240–57. https://doi.org/10.1080/09515089.2023.2266454.
Gerken, Mikkel. 2020. ‘Public Scientific Testimony in the Scientific Image’. *Studies in History and Philosophy of Science Part A* 80 (April): 90–101. https://doi.org/10.1016/j.shpsa.2019.05.006.
Gieryn, Thomas F. 1983. ‘Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists’. *American Sociological Review* 48 (6): 781–95. https://doi.org/10.2307/2095325.
Goldenberg, Maya J. 2021. *Vaccine Hesitancy*. University of Pittsburgh Press. https://doi.org/10.2307/j.ctv1ghv4s4.
Jamieson, Kathleen Hall, Dan M. Kahan, and Dietram A. Scheufele, eds. 2017. *The Oxford Handbook of the Science of Science Communication*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190497620.001.0001.
Janik, Allan. 2006. ‘Notes on the Origins of Fleck’s Concept of “Denkstil”’. In *Cambridge and Vienna: Frank P. Ramsey and the Vienna Circle*, edited by Maria Carla Galavotti, 179–88. Dordrecht: Springer Netherlands. https://doi.org/10.1007/1-4020-4101-2_12.
Jarnicki, Paweł. 2022. ‘Stimmung/Nastrój as Content of Modern Science: On Musical Metaphors in Ludwik Fleck’s Theory of Thought Styles and Thought Collectives’.

Foundations of Science 27 (3): 1207–28. https://doi.org/10.1007/s10699-021-09792-3.
Jensen, Eric. 2014. 'The Problems with Science Communication Evaluation'. *Journal of Science Communication* 13 (1): C04. https://doi.org/10.22323/2.13010304.
Kitta, Andrea, and Daniel S. Goldberg. 2017. 'The Significance of Folklore for Vaccine Policy: Discarding the Deficit Model'. *Critical Public Health* 27 (4): 506–14. https://doi.org/10.1080/09581596.2016.1235259.
Lackner, Simone, Frederico Francisco, Cristina Mendonça, André Mata, and Joana Gonçalves-Sá. 2023. 'Intermediate Levels of Scientific Knowledge Are Associated with Overconfidence and Negative Attitudes towards Science'. *Nature Human Behaviour* 7 (9): 1490–1501. https://doi.org/10.1038/s41562-023-01677-8.
Lederman, Norman G., Judith S. Lederman, and Allison Antink. 2013. 'Nature of Science and Scientific Inquiry as Contexts for the Learning of Science and Achievement of Scientific Literacy'. *International Journal of Education in Mathematics, Science and Technology* 1 (3): 138–47.
Lewis, Jamie, Andrew Bartlett, Hauke Riesch, and Neil Stephens. 2023. 'Why We Need a Public Understanding of Social Science'. *Public Understanding of Science* 32 (5): 658–72. https://doi.org/10.1177/09636625221141862.
Lohse, Simon, and Stefano Canali. 2021. 'Follow *the* Science? On the Marginal Role of the Social Sciences in the COVID-19 Pandemic'. *European Journal for Philosophy of Science* 11 (4): 99. https://doi.org/10.1007/s13194-021-00416-y.
Longino, Helen E. 2002. *The Fate of Knowledge*. Princeton, NJ: Princeton University Press. https://doi.org/10.1515/9780691187013.
Martin, Neil, Penny Buykx, Colin Shevills, Claire Sullivan, Lynsey Clark, and Dorothy Newbury-Birch. 2018. 'Population Level Effects of a Mass Media Alcohol and Breast Cancer Campaign: A Cross-Sectional Pre-Intervention and Post-Intervention Evaluation'. *Alcohol and Alcoholism* 53 (1): 31–38. https://doi.org/10.1093/alcalc/agx071.
Miller, Jon D. 1983. 'Scientific Literacy: A Conceptual and Empirical Review'. *Daedalus* 112 (2): 29–48.
———. 1998. 'The Measurement of Civic Scientific Literacy'. *Public Understanding of Science* 7 (3): 203–23. https://doi.org/10.1088/0963-6625/7/3/001.
Mößner, Nicola. 2016. 'Scientific Images as Circulating Ideas: An Application of Ludwik Fleck's Theory of Thought Styles'. *Journal for General Philosophy of Science* 47 (2): 307–29. https://doi.org/10.1007/s10838-016-9327-y.
Pew Research Center. 2015. 'Public and Scientists' Views on Science and Society'. https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2015/01/PI_ScienceandSociety_Report_012915.pdf.
———. 2023. 'Americans' Trust in Scientists, Positive Views of Science Continue to Decline'. https://www.pewresearch.org/science/2023/11/14/americans-trust-in-scientists-positive-views-of-science-continue-to-decline/.
Pickersgill, Martyn, and Matthew Smith. 2021. 'Expertise from the Humanities and Social Sciences Is Essential for Governmental Responses to COVID-19'. *Journal of Global Health* 11: 03081–03081. https://doi.org/10.7189/jogh.11.03081.
Pigliucci, Massimo, and Maarten Boudry. 2010. 'Why Machine-Information Metaphors Are Bad for Science and Science Education'. *Science & Education* 20 (May): 453–71. https://doi.org/10.1007/s11191-010-9267-6.
Rudolph, John L. 2023. *Why We Teach Science (and Why We Should)*. Oxford University Press. https://doi.org/10.1093/oso/9780192867193.001.0001.

Salmon, Rhian A., Rebecca K. Priestley, and Joanna Goven. 2017. ‘The Reflexive Scientist: An Approach to Transforming Public Engagement’. *Journal of Environmental Studies and Sciences* 7 (1): 53–68. https://doi.org/10.1007/s13412-015-0274-4.

Sample, Matthew. 2022. ‘Science, Responsibility, and the Philosophical Imagination’. *Synthese* 200 (2): 79. https://doi.org/10.1007/s11229-022-03612-2.

Scheufele, Dietram A. 2022. ‘Thirty Years of Science–Society Interfaces: What’s next?’ *Public Understanding of Science* 31 (3): 297–304. https://doi.org/10.1177/09636625221075947.

Seethaler, Sherry, John H. Evans, Cathy Gere, and Ramya M. Rajagopalan. 2019. ‘Science, Values, and Science Communication: Competencies for Pushing Beyond the Deficit Model’. *Science Communication* 41 (3): 378–88. https://doi.org/10.1177/1075547019847484.

Simis, Molly J., Haley Madden, Michael A. Cacciatore, and Sara K. Yeo. 2016. ‘The Lure of Rationality: Why Does the Deficit Model Persist in Science Communication?’ *Public Understanding of Science* 25 (4): 400–414. https://doi.org/10.1177/0963662516629749.

The Royal Society. 1985. ‘The Public Understanding of Science’. London: The Royal Society.

Trench, Brian. 2008. ‘Towards an Analytical Framework of Science Communication Models’. In *Communicating Science in Social Contexts: New Models, New Practices*, edited by Donghong Cheng, Michel Claessens, Toss Gascoigne, Jenni Metcalfe, Bernard Schiele, and Shunke Shi, 119–35. Dordrecht: Springer Dordrecht. https://doi.org/10.1007/978-1-4020-8598-7_7.

Turney, Jon. 1998. ‘To Know Science Is to Love It? Observations from Public Understanding of Science Research’. London: Committee on the Public Understanding of Science (COPUS).

UK House of Commons, Science and Technology Committee. 2017. ‘Science Communication and Engagement’. Eleventh report. London: UK House of Commons. https://publications.parliament.uk/pa/cm201617/cmselect/cmsctech/162/162.pdf.

UK House of Lords, Select Committee on Science and Technology. 2000. ‘Science and Society’. Third report. London: UK House of Lords. https://publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3802.htm.

Wynne, Brian. 1989. ‘Sheepfarming after Chernobyl: A Case Study in Communicating Scientific Information’. *Environment: Science and Policy for Sustainable Development* 31 (2): 10–39. https://doi.org/10.1080/00139157.1989.9928930.

———. 2006. ‘Public Engagement as a Means of Restoring Public Trust in Science – Hitting the Notes, but Missing the Music?’ *Community Genetics* 9 (3): 211–20.

Young, Ben, Sarah Lewis, Srinivasa Vittal Katikireddi, Linda Bauld, Martine Stead, Kathryn Angus, Mhairi Campbell, et al. 2018. ‘Effectiveness of Mass Media Campaigns to Reduce Alcohol Consumption and Harm: A Systematic Review’. *Alcohol and Alcoholism* 53 (3): 302–16. https://doi.org/10.1093/alcalc/agx094.