



Scientific progress: By-whom or for-whom?

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ABSTRACT

When science makes cognitive progress, *who* or *what* is it that improves in the requisite way? According to a widespread and unchallenged assumption, it is the cognitive attitudes of scientists themselves, i.e. the agents *by whom* scientific progress is made, that improve during progressive episodes. This paper argues against this assumption and explores a different approach. Scientific progress should be defined in terms of potential improvements to the cognitive attitudes of those *for whom* progress is made, i.e. the receivers rather than the producers of scientific information. This includes not only scientists themselves, but also various other individuals who utilize scientific information in different ways for the benefit of society as a whole.

1. Introduction

Philosophical discussions of scientific progress focus on what type of developments in science are cognitively progressive, such as when one theory replaces another in a way that constitutes an improvement. Extant accounts of scientific progress primarily disagree on what kind of cognitive change constitutes scientific progress. For example, the epistemic account developed by Bird (2007, 2016) holds that progress consists in accumulation of knowledge, while the truthlikeness account of Popper (1965, 1979) and Niiniluoto (1980, 2014) holds that progress consists in the increased truthlikeness of accepted theories. But *whose* cognitive states are at issue in these accounts? *Which* agents or groups are those whose cognitive states must change in the appropriate way, e.g. by gaining knowledge or increasing their theories' truthlikeness?

In so far as this issue has been discussed at all, the agents or groups in question have been assumed to be scientists themselves — or, perhaps, some subset of scientists, such as those actively working within a particular discipline (see, e.g., Dellsén, 2016; Niiniluoto, 2017; Bird, 2019). This might seem plausible or even inevitable since scientists are the agents most directly responsible for the occurrence of scientific progress. The implicit assumption, then, is that scientific progress should be defined in terms of the cognitive states of those *by whom* progress is made. Two main versions of this approach can be articulated, depending on whether progress is taken to depend on the cognitive states of individual scientists, or on the collective cognitive states of a scientific community. On both versions, however, it is exclusively the cognitive states of scientists themselves that determine whether an episode counts as scientifically progressive.

This paper explores a very different way of approaching the issue. The central idea is that scientific progress should be defined in terms of the potential cognitive states of those *for whom* progress is made. This includes not only scientists themselves, but also other members of society at large whose being in those cognitive states might benefit society in various ways, e.g., medical professionals, policy makers, and educators. Roughly, then, scientific progress occurs when scientific information of the right sort is made available to relevant members of society at large, including scientists themselves but not excluding various groups of non-scientists who rely on that information for different purposes. On this approach, what determines whether a particular scientific result makes scientific progress is not whether all or some scientists come to be in any particular cognitive state; rather, what matters is whether and to what extent the result is made available to relevant members of society, e.g. in academic journals and research repositories.

This paper is organized as follows. Section 2 briefly surveys the four main accounts of scientific progress, focusing in particular on the role that cognitive states and agents play in such accounts. Section 3 articulates two versions of the implicitly received view that the cognitive agents at issue are those by whom scientific progress is made, i.e. scientists, and then presents three problems for both versions of this view. Section 4 then develops the alternative approach advertised above, according to which the relevant cognitive agents are those for whom scientific progress is made, and argues that this approach is an improvement on the received view. Section 5 concludes by summarizing and highlighting practical implications.

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2. Cognitive states in accounts of scientific progress

There are four main accounts of scientific progress in the current literature, each of which identifies progress with a distinct type of cognitive change (see Dellsén, 2018a; Niiniluoto, 2019). In brief, these are *increasing truthlikeness* (the truthlikeness account), *solving or eliminating problems* (the functional account), *accumulating knowledge* (the epistemic account), and *increasing understanding* (the noetic account). In this paper, I will not be adjudicating between these accounts, arguing that scientific progress ought to be identified with one of these types of improvement rather than another. Instead, my concern will be with a feature that is built into all of these accounts, viz. that scientific progress requires that there be some agent or agents¹ whose changing cognitive states or attitudes would constitute scientific progress.²

Consider first *the truthlikeness account* (also known as *the verisimilitudinarian account*) first proposed by Popper (1963, 1979) and subsequently developed and defended by Niiniluoto (1980, 1984, 1999, 2014, 2017) and others (e.g., Aronson et al., 1994; Cevolani & Tambolo, 2013; Kuipers, 2000; Northcott, 2013). This account holds that replacing a theory T_1 with another theory T_2 is progressive just in case T_2 's truthlikeness (i.e., verisimilitude) is greater than that of T_1 . The concept of *truthlikeness* is meant to measure the extent to which a given theory captures the whole truth about some topic or phenomenon.³ For our purposes, the crucial thing to note is that the later theory T_2 and the earlier theory T_1 will both have to be in some sense accepted, believed, endorsed, or otherwise committed to; otherwise, no good sense can be made of the idea that T_2 replaced T_1 . Even Popper, who insisted that scientists shouldn't believe the theories they propose, explicitly commits to a distinction between theories that are and aren't 'provisionally accepted', i.e. "accepted as an advance upon its predecessor, and [...] considered worthy of further experimental examination which may eventually lead to [their] refutation" (Popper, 1963, p. 247). It is of course precisely when an accepted theory is 'an advance upon its predecessor', i.e. when it is more truthlike, that scientific progress occurs according to Popper.

Consider next *the functional account* (also known as *the problem-solving account*) initially suggested by Kuhn (1970) and then developed by Laudan (1977, 1981, 1984). The functional account identifies progress with a decrease over time in the number and importance of the unsolved problems within a scientific paradigm or research tradition.⁴ Importantly for our purposes, there is no such thing as a problem *tout court*; rather, something counts as a 'problem' only relative to, and in virtue of, the research tradition within which scientists are working at a given time. Indeed, the same is true of what counts as a 'solution' to a scientific problem — that too is entirely determined by the research tradition that happens to be dominant at a given time. So what is a 'research tradition'? On Laudan's (1977, 81–95) account, it is a set of assumptions about the

entities and processes in some domain and the appropriate methods for studying them. Since these assumptions ultimately determine what counts as a problem, and indeed what counts as a solution to such a problem, the functional account is clearly committed to defining scientific progress in terms of the cognitive states of some agents, viz. those scientists whose assumptions comprise the relevant research traditions.

A third major account of scientific progress is *the epistemic account*, as formulated and defended by Bird (2007, 2016).⁵ Bird's epistemic account holds that scientific progress consists in accumulation of knowledge. Of the three accounts discussed so far, the epistemic account is perhaps most obviously committed to defining scientific progress in terms of some agents' cognitive states, viz. their knowledge. According to epistemological orthodoxy, knowledge implies belief, so in order for knowledge to accumulate there needs to be some subjects whose beliefs change. Indeed, a similar point applies even if knowledge did not imply belief, since knowledge — at least in Bird's sense of the term⁶ — requires there to be someone or something that is in a state of knowing. Interestingly, Bird (2019) has recently argued that the subject in question should be conceived of as an institution, viz. *science*, which is composed of, but not identical to, the scientists within it (see also Bird, 2010, 2014). It is this institution, this collective agent, whose knowledge accumulates in cases of scientific progress on Bird's view.

Finally, consider the original version of my own *noetic account* of progress (Dellsén, 2016; 2018b), which holds that progress consists in increasing understanding of the phenomena studied by science.⁷ This account's key notion is (objectual) *understanding*, originally defined operationally as an ability to correctly explain or predict some aspect of the understood phenomenon (Dellsén, 2016, p. 75). In more recent work (Dellsén, 2020), I have offered a slightly different definition of understanding as grasping a sufficiently accurate and comprehensive model of the understood phenomenon's dependence relations, e.g. its causal relations.⁸ For our purposes, the important thing to note is that on either of these definitions, any change in degrees of understanding clearly requires there to be an agent whose cognitive states ground understanding. Hence there can be no increase in understanding of the phenomena studied by science unless there are some subjects whose cognitive states change in the process.

Stepping back from particular accounts of scientific progress, there is a general reason why any account of scientific progress will inevitably refer, in some way or another, to actual or potential cognitive states of some agents. As Niiniluoto (2019, §2.1) notes, there are several senses in which science could be said to improve over time that aren't at issue in debates between proponents of the aforementioned accounts of scientific progress. For example, although science would improve by being better funded, by adopting more reliable ways to conduct peer review, or by increasing gender equality among scientists, these types of improvements are not at issue in the debate. Rather, following both Niiniluoto (2019, §2.1) and my earlier self (Dellsén, 2018a, p. 2), the intended explicandum of the aforementioned accounts is *cognitive scientific progress*, which can be understood broadly for our purposes so as to include any type of improvement in someone's cognitive representations, abilities, skills, or know-how — all of which are grounded in some sort of cognitive change from one time to another. Given this characterization of what different accounts of scientific progress are meant to explicate, it's inevitable for such accounts to identify progress with changes in the cognitive states of

¹ For the sake of simplicity, I will often use the plural even though some hold that there is a single collective agent whose cognitive improvements constitute progress (see §3).

² In what follows, I will for convenience often use 'cognitive attitude', or simply 'attitude', interchangeably with 'cognitive state'. I will be using these terms in a very broad sense to include not only propositional attitudes of various sorts, but also various arguably non-propositional states and attitudes, such as know-how, skills, and abilities. Thus when I refer to changes in cognitive attitudes, that should be taken to include changes and additions in know-how, skills, and abilities, as well as changes in propositional attitudes such as beliefs, acceptances, and credences.

³ Formally, the truthlikeness of a theory T is typically defined in terms of the distance between an ideal complete theory C^* , describing the world accurately in all its details, and each of the complete theories C_1, \dots, C_n 'allowed by' T , i.e. such that T is equivalent to the disjunction $C_1 \vee \dots \vee C_n$ (see, e.g., Oddie, 1986; Niiniluoto, 1987).

⁴ 'Research tradition' is Laudan's terminology; it corresponds roughly to what Kuhn initially called a 'paradigm' and later came to call a 'disciplinary matrix' (Kuhn, 1974).

⁵ Other knowledge-based accounts have been proposed by Cohen (1980), Barnes (1991), and Park (2017).

⁶ Bird (2007, 87, n.2) explicitly endorses Williamson's view of knowledge, according to which knowledge is a (mental) cognitive state (Williamson, 2000, 21–48).

⁷ See Bangu (2015), Potochnik (2015, 2017), and Rowbottom (2015, 2019) for other views on which various forms of understanding are central to scientific progress.

⁸ For alternative approaches to explicating the notion of understanding in the recent literature, see e.g. de Regt (2017), Elgin (2017), and Khalifa (2017).

some agents; otherwise the changes in question would simply not be scientific progress of the *cognitive* type that is at issue.

Another general point about accounts of scientific progress will be important in what follows. As Niiniluoto (2019, §2.2) notes, ‘progress’ is a *normative* concept in the sense that progress from *A* to *B* implies that *B* is an improvement on *A*.

Hence, the theory of scientific progress is not merely a descriptive account of the patterns of developments that science has in fact followed. Rather, it should give a specification of the values or aims that can be used as the constitutive criteria for “good science.” (Niiniluoto, 2019, §2.2).

It follows from this elementary point that an account of scientific progress does not, and should not, leave everything normatively as it was; rather, such an account directly implies normative claims about how scientists ought to behave and how their work should be organized. For example, to the extent that one’s preferred account of scientific progress counts a particular research project as more progressive than another, the account also implies, all else being equal, that scientists should be encouraged and incentivized to pursue the former project at the expense of the latter.

3. The by-whom conception of scientific progress

As detailed in the previous section, any account of scientific progress — implicitly understood to be restricted to *cognitive* progress in science — will identify it with changes in the actual or potential cognitive states of some agents. Since these accounts are also restricted to *scientific* progress, i.e. progress in or of science, it may seem inevitable that the agents in question would be scientists themselves, or perhaps some relevant subset thereof (such as those involved in the research in question). This last step does not follow from the stipulation that the type of progress in question be cognitive, since scientists are not the only agents whose cognitive states or attitudes could change as a result of scientific research. Nevertheless, this further step, in which it is assumed that the agents in question should be restricted to scientists themselves, is routinely taken in the literature. In this section, I’ll argue that this is a mistake.

To fix our terms in what follows, let us call this assumption the *by-whom conception* of scientific progress. The by-whom conception thus holds that the subjects whose cognitive states determine whether scientific progress is made are the agents who make scientific progress, i.e. scientists themselves or some subset thereof. To be clear, the by-whom conception is not an alternative to extant accounts of scientific progress; on the contrary, it is either a component of, or a complement to, any such account. Whether it is component of, or complement to, a given account of scientific progress depends on how the account is stated, i.e. whether the account is explicitly formulated so as to entail the by-whom conception.⁹

Although the by-whom conception remains implicit in most discussions of scientific progress, Niiniluoto appears to endorse it explicitly in saying that “the primary application of the notion of scientific progress concerns successive theories *which have been accepted by the scientific community*” (Niiniluoto (2017, p. 3299, emphasis added).¹⁰ Indeed, some version of the by-whom conception is presupposed in several recent

⁹ For example, my original formulation of the noetic account, “[s]cience makes (cognitive) progress precisely when scientists grasp how to correctly explain or predict more aspects of the natural world” (Dellsén, 2016, 75), makes the by-whom conception a component of the noetic account. On a slightly later formulation, “science makes progress precisely when we gain more understanding” (Dellsén, 2018a, 451), the by-whom conception complements the noetic account by specifying the extension of ‘we’. With that said, the most recent version of the noetic account (Dellsén, 2021) — which was written after this paper was first drafted — explicitly abandons the by-whom conception in favor of the for-whom conception developed below.

¹⁰ Niiniluoto (2017, 3299) refers to this as a “hidden assumption”, which indicates that he takes the by-whom conception to be widely shared.

arguments in which certain changes in scientists’ cognitive states are taken to entail, or fail to entail, that scientific progress has been made. For example, some of Bird’s (2007, 65–71) influential arguments against the truthlikeness and problem-solving accounts appeal to thought experiments in which specific scientists’ beliefs change without them obtaining any new knowledge, and in which it is meant to be intuitively clear that no scientific progress has taken place. These cases would fail to establish the intended conclusion, viz. that accumulation of knowledge is necessary for scientific progress, unless it is assumed that the scientists’ own cognitive states before and after a given episode determine whether there is scientific progress during that episode.¹¹

As some of my formulations above intimate, the by-whom conception can be developed in at least two *prima facie* plausible ways. For scientific progress to occur, it is clearly not in general sufficient that a single scientist undergoes some cognitive change, however profound, especially considering that this scientist may be isolated and uninfluential (cf. Rowbottom, 2008, p. 277; Bird, 2008, pp. 279–280). Two main alternatives thus suggest themselves (see Gilbert, 2000, pp. 37–38). The first is that a plurality or sufficiently large majority of agents in a given scientific community must come to be in the requisite cognitive state; call this *the individualist by-whom conception*. The second is that the scientific community — considered as a collective epistemic agent in its own right, capable of being in cognitive states *qua* collective — must come to be in such a state; call this *the collectivist by-whom conception*. Note that both versions of the by-whom conception hold that it is the entire scientific community that determines scientific progress; but whereas the individualist version looks to the cognitive states of the plurality or majority of individuals within this community, the collectivist version focuses on the cognitive states of the community considered as a collective agent.

In what follows, I present three distinct problems for the by-whom conception. I start by considering a thought experiment concerning the publication of scientific results, arguing on this basis that neither version of the by-whom conception can account for the central role of publishing in scientific progress (§3.1). I then argue that both versions of the by-whom conception are forced to set down a problematically arbitrary boundary between who is and who isn’t included in the relevant scientific community (§3.2). Finally, and most significantly, I argue that the by-whom conception cannot adequately explain what makes scientific progress valuable to a society (§3.3).

3.1. Publication and collective/individual cognitive states

The two versions of the by-whom conception described above differ with regard to whether scientific progress is taken to be determined by changes in individual or collective cognitive states, i.e. the cognitive states of individual scientists or the cognitive states of collectives of such scientists. In this subsection, I will first consider an argument against the individualist by-whom conception that has been put forward by proponents of the collectivist by-whom conception. Although this argument is supposed to support the collectivist by-whom conception over its individualist counterpart, I will argue that it counts against the collectivist version as well, thus undermining both versions of the by-whom conception considered above.

In a recent discussion of cognitive progress in science and philosophy, Ross (2020, pp. 7–8) adopts an example used in a slightly different context by Bird (2010, 2014), to show that cognitive progress can occur even when none of the scientific community’s members come to be in the requisite cognitive state. Here is Bird’s original version of the example:

Dr N. is working in mainstream science, but in a field that currently attracts only a little interest. He makes a discovery, writes it up and

¹¹ The by-whom conception also appears to be implicitly assumed in arguments given by, among others, Rowbottom (2008, 277–278), Dellsén (2016, 76–77), and Park (2017, *passim*).

sends his paper to the *Journal of X-ology*, which publishes the paper after the normal peer-review process. A few years later, at time *t*, Dr N. has died. All the referees of the paper for the journal and its editor have also died or forgotten all about the paper. The same is true of the small handful of people who read the paper when it appeared (Bird, 2010, p. 32).

Ross and Bird both take Dr N.'s discovery to count as scientific progress at the time of publication,¹² and to remain so even after Dr N. and his colleagues die. On their view, this is because the publication of Dr N.'s discovery changes the collective attitudes of the scientific community, e.g. (in Bird's case) in that the community thereby comes to *collectively know* about the discovery. Importantly, the episode remains progressive in their view even as the individuals involved disappear from the scene along with all of their individual attitudes.

Although inevitably somewhat artificial, hypothetical examples of this kind point to a fundamental problem at the heart of the individualist by-whom conception, viz. that on reflection it seems irrelevant what cognitive attitudes individual scientists happen to have or lack at a given time if those attitudes are in no way reflected in their published results, either presently or in the future. Bird (2014, 2019) and Ross (2020) both suggest that this problem is avoided by the collectivist by-whom conception, in which the cognitive attitudes that are taken to be relevant to scientific progress are those of the scientific community considered as a single collective agent. The idea is that if collective attitudes are not simply agglomerations of the individual attitudes of those who comprise the collective, then the collective may have the requisite attitude in these types of cases even when none of the individuals do; and, conversely, the collective may lack the requisite attitude even when it is possessed by all of its members. Thus it may seem that Bird's case of Dr N. simultaneously refutes the individualist version of the by-whom conception and supports the collectivist version.

Before I get to what I consider to be the main problem with this line of reasoning, I want to call attention to the fact that in order for the above argument to support a collectivist version of the by-whom conception, one must be prepared to depart quite radically from mainstream thinking about the nature of collective attitudes. On the most influential accounts of collective attitudes in the philosophical literature, e.g. those of Gilbert (1989, 1994), Toumela (1992, 2004), Schmitt (1994), and Pettit (2003), a group does not count as having a collective attitude unless it displays a certain degree of cohesion and its individual members are in some sense committed to the joint resolution of the group. In Gilbert's influential terminology, the relevant groups must be 'established'. At a minimum, this requires that the members of the group have expressed a commitment to let the relevant proposition stand as the collective attitude of the group, e.g. through voting on the proposition. For example, the philosophy faculty at a university does not count as a collective agent merely in virtue of the fact that we can refer to them with a collective noun ('the philosophy department'); rather they count as a collective in virtue of the procedures in place for collective deliberation, e.g. at department meetings, to which its individual members are committed.

It is doubtful that anything like this requirement is always or even typically satisfied in paradigmatic cases of scientific progress. Scientific communities rarely have mechanisms for their members to express this type of commitment with regard to the theories or results obtained by its other members.¹³ To be sure, there are cases in which collective statements are

¹² In Bird's case, this follows from his taking the scientific community to have collective knowledge as soon as Dr N.'s discovery is published (Bird, 2010, 32–3), in conjunction with his view that progress is accumulation of (collective) knowledge (see esp. Bird, 2014, 2019).

¹³ Of course, scientists discuss, debate and eventually often come to agree on various claims and theories; but these sorts of informal processes are a far cry from the deliberate procedures that are envisioned by mainstream theorists of collective attitudes such as Gilbert (1989, 1994), Toumela (1992, 2004), Schmitt (1994), and Pettit (2003).

issued to reflect the opinions of entire scientific communities,¹⁴ but such cases are very much the exception rather than the rule. More to the point, the requirement that group members be committed to letting the relevant proposition stand as the collective attitude of the group is clearly not satisfied in Bird's case of Dr N., since all the members of the relevant group who might be so committed have died at the end of the episode; indeed, the scientists that remain are not even aware of Dr N.'s discovery. Thus, in order for Bird's and Ross's argument to support a collectivist by-whom conception, we would need to move away from mainstream accounts of collective attitudes, and adopt an extremely inclusive account on which a group may have a collective attitude regarding some claim even though its current members have never even so much as considered that claim.¹⁵

Now let me set aside the issue of whether the resulting by-whom conception, with its radically inclusive view of collective attitudes, would be plausible. Consider instead whether it would receive any support from Bird's case of Dr N. My contention is that if the case of Dr N. provides an argument against the individualist by-whom conception, then it also provides an argument against the collectivist version. In short, this is because there is no reason to think that collective attitudes of scientific communities — assuming, for the sake of the argument, that there are such collective attitudes — are necessarily reflected in scientific publications of any sort, as would be required for this maneuver to provide the desired result that there is progress in the case of Dr N. To see this, note that in the case of individual attitudes, it is clearly possible to have a cognitive attitude and yet fail to express it (e.g., when keeping a secret). Indeed, it's also possible to express something that contradicts one's cognitive attitude (e.g., when lying about it). So why couldn't a scientific community have a collective attitude that it fails to express — accurately, or at all — in its published results? Indeed, some reflection reveals that it is clearly possible for collective attitudes to come apart from what is published by the collective or its individual members.¹⁶

¹⁴ As in the statements that have been issued on anthropogenic climate change (Joint Statement, 2001) and evolution by natural selection (American Association for the Advancement of Science, 2006).

¹⁵ A proponent of the collectivist by-whom conception might of course simply endorse this conclusion by jettisoning the requirement that the relevant collectives display any degree of cohesion, i.e. that the collectives be 'established' groups in Gilbert's sense. Accordingly, my remaining arguments against the collectivist for-whom conception do not assume that such a requirement must be made. However, it is worth noting that this move leaves proponents of the collectivist by-whom conception with the task of saying precisely what makes these collections of scientists into a collective agent at all, and in what sense these collective agents would have cognitive attitudes. Consider, in particular, Bird's (2010; 2014) own account, according to which collective knowledge can be defined by functional analogy with individual knowledge. Briefly, on Bird's view, a collective agent knows that P just in case P is the output of a cognitive structure whose function it is to reliably produce true outputs, where these outputs can themselves either serve as inputs for collective action or be fed back into the cognitive structure to produce further truths (Bird, 2010, 42–46). However, as Lackey (2014) argues, Bird's concept of social knowledge has problematic consequences for the connection between knowledge and action, on the one hand (2014, 285–291), and knowledge and defeaters, on the other hand (2014, 291–294); moreover, it is unclear what role social knowledge of Bird's variety is supposed to play that couldn't already be played by the notion of being in a position to know (2014, 294–295).

¹⁶ It has been suggested to me that publishing results might serve a function in scientific communities that is analogous to the function served by memory in individuals. If so, the suggestion goes, publication just is a type of collective attitude on Bird's (2010; 2014) functionalist account of collective attitudes. I have two related responses to this suggestion: First, it would make the scenario described in the main text below conceptually or metaphysically impossible. I think it is clear that it is not; hence the suggestion must be false. Second, there is an important disanalogy between (individual) memory and (collective) publication: an individual's memory is private to that individual in the sense that other agents cannot directly access the content of the individual's memory; by contrast, a scientific community's publication is clearly not private to that community, since outsiders can also directly access the contents of that publication. (Thanks to an anonymous reviewer.)

To illustrate with another fanciful example, suppose that a community of medical researchers working on a specific disease were to collectively discover a quick and permanent cure that would make all their other research irrelevant. In order to protect their field and their future careers, they collectively decide to keep the discovery secret, e.g. by preventing publication in the field's academic journals.¹⁷ Note that the decision not to publish information about the cure is based on the collective having various attitudes towards the cure, e.g. that it is indeed effective against the disease, which is precisely what they choose to conceal in a systematic manner. Thus, in this case, the collective attitude of the relevant scientific community is clearly not reflected in its published results. The upshot of this example, then, is that collective attitudes are not identical, because not necessarily coextensive, with the published results of the collective or its members.¹⁸

With this in mind, let us return to the Bird's case of Dr N. Suppose, with Bird and Ross, that it is indeed correct to count Dr N. as having made progress in virtue of *publishing* his discovery. As we have seen, however, publication can come apart from collective attitudes, so Dr N.'s discovery cannot then count as progressive in virtue of a change in the scientific community's collective attitudes. Now, admittedly, Bird's description of the case certainly leaves it open that the community of which Dr N. was a member *also* came to change its collective attitudes in the relevant way. It is not hard to imagine, for example, that the scientific community came to collectively accept or know about Dr N. discovery *as a causal consequence* of its publication. Nevertheless, if Bird and Ross are correct in counting Dr N. as having made progress at the time of publication, then it follows from the description of the case that the collective attitudes of the community are strictly speaking irrelevant to whether Dr N.'s discovery constitutes progress. So, appearances perhaps to the contrary, collectivists like Bird and Ross cannot adequately account for cases of this sort, where it is by their own lights the publication of Dr N.'s discovery (rather than, say, the causal effects of that publication) that make it scientifically progressive.

Indeed, we can construct another fanciful example that puts pressure on the collectivist by-whom conception in much the same way as Bird's case of Dr N. does for the individualist by-whom conception. Suppose that everything is the same as in Bird's original case except that when Dr N. dies, i.e. at time *t*, every other member of the scientific community also tragically dies (perhaps in some terrible pandemic). Happily, however, Dr N.'s excellent paper in the *Journal of X-ology* continues to be accessible online and at libraries, so that Dr N.'s discovery is easily consulted by other surviving members of the public. Assuming only that collective attitudes cannot be had by non-existing collectives (or by 'collectives'¹⁹ that have no members), this cannot possibly be a case of the scientific community having a collective attitude at *t*. Still, this seems just as clear a case of scientific progress as the original case of Dr N.: In both cases, it is the publication of the result, rather than the attitudes of the scientific community (or its individual members), that makes it a plausible case of scientific progress.

A proponent of the collectivist by-whom conception could respond to these cases by *stipulating* that the collective attitudes of a scientific community just are whatever is published in that community's scientific

journals. This would ensure, by brute force, that there would be no distance between collective attitudes and published results. However, there are at least two problems with this response. First, to paraphrase Russell (1919, p. 71), this response has all the advantages of theft over honest toil, in that it fails to *explain* why the published results would determine collective cognitive attitudes in the required way. Put differently, the collectivist by-whom conception would be forced to stipulate that, rather than explain why, the types of cases that tell against the individualist by-whom conception do not equally tell against the collectivist version. Second, stipulating that collective attitudes of scientific communities must be published raises the issue of how to explain what is going on in the example of medical researchers preventing publication on a new cure, where it certainly seems that the scientific community has a collective attitude in virtue of which scientists collectively decide not to publish the contents of that very attitude. Stipulating that collective attitudes be reflected in publications thus prevents proponents of the collectivist by-whom conception from explaining the community's collective behavior in terms of their collective attitude towards the cure.²⁰

3.2. The extension of 'the scientific community'

Let us now set aside the distinction between the individualist and the collectivist by-whom conception, and instead consider a problem for the by-whom conception which applies in the same way to both versions of this conception. To a first approximation, the problem concerns how exactly to delimit the extension of 'the scientific community' to which this conception refers in a way that sustains the normative weight that is being put on this concept. Who counts as a member of the scientific community such that changes in the cognitive attitudes of this community, or the individuals who comprise it, determine whether a given episode constitutes scientific progress? In order to fully convey the difficulty here, I will start by considering an easier version of this problem, and then move on to a much harder problem in the vicinity.

The easy problem is simply to precisely specify the extension of 'the scientific community' in light of the inherent vagueness of the term. This is really less of a problem and more of a choice between different ways of spelling out the by-whom conception, where its proponents are simply free to develop the conception in whatever way they prefer. In particular, they might variously take the relevant community to include, for example, (i) all scientists, (ii) scientists within a specific discipline (e.g. molecular biologists), or (iii) just the scientists directly involved in obtaining the relevant result (e.g. the members of a specific lab).²¹ On each way of delimiting the extension of the relevant community, i.e. on each of the options (i)-(iii), it seems that a proponent of the by-whom conception will be forced to make some arbitrary choices about who should and shouldn't be included in the relevant group or community. For example, suppose one thinks that the most plausible version of the by-whom conception restricts 'the scientific community' to (ii), i.e. the scientists within a specific discipline. This would raise a number of questions about who gets to be included in this group: Do postdocs count? How about doctoral students and lab assistants? What about collaborators from nearby fields? And are the relevant scientists required to have a formal education of some sort? If so, what type of degree must they have? Which institutions qualify? Moreover, where exactly should we draw the line between scientists in this scientific discipline and those in other nearby disciplines? What about interdisciplinary research? And so on.

The easy problem, then, is about where to draw the line in these respects. This problem is 'easy', however, in the sense that a proponent of

¹⁷ Indeed, this example may not be so fanciful after all, since there are real-life cases of publication of important findings being obstructed or delayed for dubious reasons (see, e.g., Kaiser, 1996; Solomon, 1996). (Thanks to another anonymous reviewer.)

¹⁸ This example has been constructed to concern the collective attitude of a specific scientific community, viz. a community of medical researchers, but it could obviously be modified so as to concern a larger community of scientists, e.g. the community of all scientists.

¹⁹ The scare quotes are of course meant to signal that it is implausible that there could exist any empty collectives of this sort at all. When all members of the scientific community cease to exist, then so does the scientific community itself. But my argument in the main text goes through even if there are empty collectives, as long as they cannot be said to have collective attitudes.

²⁰ A potential third problem with this response is that it implies that in the modified Dr N.-case (where all scientists die at time *t*), there is still (at time *t*) a collective attitude of the scientific community.

²¹ I am not suggesting these options are exhaustive; I include them here merely to illustrate the types of options that are available to proponents of the by-whom conception.

the by-whom conception could choose to answer such questions however they like, setting down a (perhaps somewhat arbitrary) boundary between scientists and non-scientists. In other words, they may simply stipulate an extension of ‘the scientific community’, e.g. to include doctoral students but not lab assistants. But this gets us to the hard problem.

The hard problem is that by stipulating an extension of ‘the scientific community’, proponents of the by-whom conception would implicitly be deciding which episodes count as scientifically progressive on their view. For example, the inclusion of a skeptical lab assistant, or the exclusion of a convinced doctoral student, might tip the balance for or against a particular episode counting as scientifically progressive. On the individualist by-whom conception, it might be precisely in virtue of that person’s individual attitudes that a plurality or sufficiently large majority of the members of the relevant scientific community obtain the cognitive attitudes required for progress. Similarly, on the collectivist by-whom conception, it might be precisely in virtue of that person’s contribution to the scientific community’s collective attitudes that the community counts as having the collective attitude required for progress. The question, then, is whether it is really plausible that scientific progress would be sensitive in this way to seemingly arbitrary distinctions between who is and isn’t classified as part of ‘the scientific community’.

If not, then the difficulty here is not merely where to draw the line (the easy problem), but that there is no relevant line to be drawn at all (the hard problem). That is, any distinction between members and non-members of the relevant scientific community seems, on reflection, unable to carry the normative weight of separating what does from what doesn’t count as scientific progress. Thus the real (hard) problem is not merely due to the fact that ‘the scientific community’ is a vague term; rather, it is due to that fact that its extension — which may or may not be indeterminate in certain borderline cases, due to the vagueness of the term itself — simply does not seem to be the sort of thing that could ultimately determine whether scientific progress has been made in a given case. Indeed, recall that the concept of scientific progress is a partially normative one, in that describing an episode as scientifically progressive implies normative claims about how scientists should, and should be incentivized to, plan and do research. The by-whom conception thus implies, implausibly in my view, that normative decisions about issues of this sort should depend in part on what we end up counting as the extension of ‘the scientific community’.

One might object that issues of this sort, having to do with the precise extension of a term like ‘the scientific community’, will be anyone’s problem. After all, won’t *any* account how scientific progress is determined by some agents’ actual or potential cognitive states at different times have to set down some sort of boundary around the agents whose actual or potential cognitive states are and aren’t relevant? Well, yes, but the (hard) problem for the by-whom conception runs much deeper than this. That problem is not merely a matter of having to draw the line somewhere, and so that any precise way of doing so would be arbitrary. Rather, the problem is that what we would count as scientifically progressive seems to float completely free of how we would be inclined to (perhaps arbitrarily) draw this line, e.g. by including a skeptical lab assistant or excluding a convinced doctoral student. After all, does it really seem plausible that whether, or the extent to which, a given episode should count as scientific progress might depend on whether lab assistants, for example, are counted as ‘scientists’ or not?²²

²² In section 4, I consider whether a version of this argument against the by-whom conception also applies to the for-whom conception developed there. I argue that it does not, because although the latter conception must draw a line (perhaps somewhat arbitrarily) between those who do and don’t count as ‘members of society’, this distinction — even if vague or indeterminate — is plausibly able to carry the normative weight put on it by the for-whom conception.

3.3. The societal value of scientific progress

A final, and in my view most fundamental, problem with the by-whom conception is revealed when we ask ourselves what it is about scientific progress that makes it valuable in the first place. Indeed, what makes it so valuable that a substantial proportion of public spending in developed countries goes toward attempts at achieving it, i.e. toward scientific research? The answer is surely not that scientific progress is valuable exclusively in virtue of changing or improving the attitudes of scientists themselves (or some proper subset thereof), considered either as individuals or as a collective. Such an answer would explain only why the scientists themselves should value scientific progress — in a way analogous to how someone would explain why they value their own learning. It would not explain why non-scientists should also value scientific progress — or indeed why entire societies, mostly made up of non-scientists, should value it.

To substantiate this concern, recall (from §2) that scientific progress is a normative concept. To say that scientific progress occurs during some episode is to say that science has cognitively *improved* during that episode, i.e. that science is in a cognitively better state after the episode than before it. Given that the science funded by a given society is, or ought to be, for everyone in that society, what reason is there to restrict the cognitive attitudes that are taken to determine whether scientific progress is made to those held by a select group within the society, viz. scientists or some proper subset thereof? The fact that scientists are those who are most directly responsible for achieving scientific progress is neither here nor there,²³ since it is clearly not a logical or normative principle that those directly responsible for an achievement must receive all the benefits from it.

So if scientific progress is meant to be valuable, not just to the small segment of society that comprises the relevant scientific community, but also in some way to us all, then the value of scientific progress cannot merely consist in its improving scientists’ own cognitive attitudes. The obvious response on behalf of the by-whom conception is to point out that scientific research typically has various practical benefits that are enjoyed by scientists and non-scientists alike, such as technological advances, improved medical treatments, and more effective social policies. These practical benefits, the response would continue, arise as a result of the improved cognitive states of scientists themselves. Thus it might seem that the by-whom conception can explain the value of scientific progress by appealing to the various practical benefits that arise from scientific research.

There are two problems with this response — one of which is obvious and the other less so. The obvious problem is that not all scientific research has, or is expected to have, any practical benefits at all — or, at any rate, not enough to justify the amount of public funds spent on it. For example, CERN’s Large Hadron Collider (LHC), at a total cost of around \$4.75 billion, is rarely expected to lead to practical benefits that would by themselves justify its price tag, for there are surely more cost-effective ways of achieving whatever practical benefits we could trace to the LHC. Rather, the central rationale for building the LHC explicitly concerned the purely theoretical discoveries it makes possible (see, e.g., [Llewellyn Smith, 2015](#)). Now what explains the value of making scientific progress in this type of ‘pure’ research, where the practical benefits for non-scientists are at best unclear and possibly non-existent? At least for that type of research, the answer cannot be that the cognitive improvement undergone by scientists themselves leads to practical benefits of the sort that would suffice to justify extensive public spending on it.

But can the by-whom conception at least explain what makes scientific progress valuable in the remaining cases, i.e. cases where scientific research leads to — or are expected to lead to — practical benefits of various kinds? I don’t think so. (This is the less obvious problem.) Note that a scientific discovery or its acceptance by a scientific community would not

²³ Although it is perhaps worth noting that many other members of society will be indirectly responsible for achieving scientific progress, e.g. science-funding officials, policy makers, tax payers, and even consumers.

by itself normally lead to practical benefits to anyone outside of that community unless the discovery is communicated to individuals who are in a position to utilize it in various ways. For example, the discovery that a certain group of individuals are genetically predisposed to a particular disease would have little or no practical benefits unless it is communicated to medical professionals who are able to use this information to diagnose the disease and help prevent it. Similarly, the discovery of a new type of superconductor would not by itself lead to any technological advances; rather, it does so only if this information is communicated to engineers or others who would use it to develop the relevant technologies.

In these cases, in order for the relevant results to have significant practical benefits, it is clearly not sufficient that the researchers themselves, or the communities they comprise, have some particular cognitive attitudes towards these results. If the results are not communicated to anyone outside of these communities, they will be of little practical value. So, even in cases where scientific results do lead to practical benefits, it is not the changing cognitive attitudes of scientists themselves that explain the value of such research, contrary to what the by-whom conception would have to claim. Rather, the practical benefit of scientific research is explained by the fact that the results in question are communicated to the parties who are in a position to utilize these results for practical gain, e.g. medical professionals, engineers, and policy makers.

To my mind, this is the most fundamental problem for the by-whom conception, because it doesn't just indicate that this conception should be rejected; it also points towards an alternative way of thinking about the issue. On this alternative conception, scientific progress is conceived of not in terms of improvements in the cognitive attitudes of a scientific community or its members, but in terms of how the communication of scientific results make it possible for them *and others* to improve their cognitive attitudes in the requisite way. In the next section, I flesh out and defend this idea.

4. The for-whom conception of scientific progress

When a scientific result of some kind has been established, e.g. through an experiment or theoretical argument, that is not the end of the matter as far as the scientific enterprise is concerned. Rather, it is the beginning of a process in which the aim is for the result to be communicated to others, usually in a scientific journal or research repository. Nowadays there are mechanisms, such as peer review, for ensuring that the results that are communicated in these ways meet some minimum standards of reliability or adequacy. A result that makes it through this process is no longer exclusive to those who produced the results, e.g. the relevant lab or researcher; rather, it can be accessed and utilized by various other members of society, at least in principle. Let us call this *public information*. Thus, a piece of information is public when it has been communicated, typically in the form of a journal article, in such a way as to be in principle accessible by various individuals that did not themselves author, produce, or contribute to it.²⁴

²⁴ Kitcher (2011, 85–104) develops a similar notion of ‘public knowledge’ in a quite different context. However, I prefer ‘public information’ because formulating the for-whom conception in terms of knowledge (with the epistemic requirements thereby implied) might commit it to a version of the epistemic account of scientific progress, whereas I intend to be neutral between accounts of scientific progress.

The notion of ‘public information’ might also be reminiscent of Popper's notion of ‘objective knowledge’, developed as part of his “epistemology without a knowing subject” (Popper, 1979, 106–152). However, Popper's notion refers to entities that exist (according to Popper) in a “third world” of “possible objects of thought” (Popper, 1979, 154), which is meant to be distinct from the physical (“first world”) and the mental (“second world”). Indeed, Popper explicitly indicates that the contents of ‘objective knowledge’ need not have been communicated at all (Popper, 1979, 107). By contrast, what I am calling public information must at some point have been communicated, e.g. via an academic journal, and is firmly located in physical reality, e.g. in the hard drives of computer servers.

A couple of clarifications are in order. First, accessing public information may often be difficult or costly, as when academic journals charge a fee for reading its articles. But in contrast to various bits of information that are either not communicated at all or only communicated to a select group of individuals (such as one's political opinions), public information has been intentionally communicated to an unrestricted audience in a way that makes it legitimate for anyone to cite and refer to that information elsewhere. Second, to say that public information is accessible to someone is not to say that it is in fact ever accessed by them. They may lack the time, or the interest, to do so. Nevertheless, public information is valuable in so far as it has the potential for informing the individuals that do have access to it, including most importantly those who are tasked with utilizing the information in question for the benefit of society as a whole. For example, public information on COVID-19, contained in various scientific articles, has benefitted us all in so far as it has informed medical professionals, policy makers, and others who have been tasked with curbing the pandemic.

For our purposes, the crucial thing about public information is that relevant members of society could in principle use such information to form or shape their cognitive attitudes.²⁵ The kinds of cognitive attitudes in question can be any of those to which different accounts of scientific progress refer, i.e. truthlike acceptance, a research tradition's assumptions, knowledge, or understanding. Thus we can reconceive of these accounts of scientific progress as concerning not how progress is determined by the cognitive attitudes actually held by scientists at different times, but by how public information produced by scientific research enables various individuals to form the relevant kind of cognitive attitudes. For example, we can reconceive of the epistemic account as holding not that progress consists in accumulating knowledge among scientists, but in altering the state of public information so as to make it possible for those who thereby have access to this information to accumulate knowledge.

I will refer to this way of reconceiving of accounts of scientific progress as *the for-whom conception*. The for-whom conception is an alternative to the by-whom conception discussed in the previous section, which defined progress in terms of the cognitive attitudes of the *producers* of scientific research. By contrast, the current proposal is to define progress in terms of the *receivers* of scientific research. Specifically, the for-whom conception holds that whether an episode is scientifically progressive depends on whether changes in public information during that episode enables those who thereby have access to it to acquire or modify the requisite cognitive attitudes — where the nature of the ‘requisite’ cognitive attitudes depends on which of the four accounts of scientific progress one prefers. The for-whom conception is thus either a complement to, or modification of,²⁶ traditional accounts of scientific progress, in that it specifies (in what is perhaps an unexpected way) whose cognitive attitudes are at issue and what is the required relationship between the scientific research itself and the cognitive attitudes in question.

Now, although the for-whom conception defines scientific progress in terms of the receivers rather than the producers of scientific knowledge, it is worth emphasizing that there is a great deal of overlap between these two groups. Science is a largely cumulative enterprise in which new results build on previous work, so much of scientific research is primarily meant to be communicated to other scientists. Put differently, the primary receivers of the public information produced in science are very often scientists themselves. Indeed, making scientific results accessible to other scientists is a great way to *promote* scientific progress (Bird, 2007, p. 280; Dellsén, 2016, p. 73). From the for-whom conception's point of view, there is thus a kernel of truth in the by-whom conception's focus on the cognitive changes undergone by scientists themselves, i.e. in so far as

²⁵ Recall that I am using ‘cognitive attitudes’ in a broad sense that includes, e.g., know-how, skills, and abilities. See footnote 2.

²⁶ See footnote 9 and the paragraph to which it is attached.

it is particularly important that scientists have access to scientific information in order to promote further progress on related topics.

As I have indicated, a central motivation for the for-whom conception comes from considering the normative question of why a society should value scientific progress in the first place; indeed, why it should value it to such an extent that non-scientists should be prepared to contribute to it through extensive public funding of scientific research (see §3.3). On the for-whom conception, a society has reason to value scientific progress, and thus contribute financially to scientific research, because and in so far as it benefits society as a whole, e.g. through making biomedical results available to medical professionals. On this view, even making progress in ‘pure’ research benefits society as a whole in so far as it makes information available to laypeople, whose cognitive attitudes might thereby improve – and, perhaps more importantly, to science educators and journalists, who are specifically tasked with informing laypeople about scientific results. In short, scientific progress is valuable because and in so far as it helps to make accessible, to relevant members of society, information that has practical or cognitive benefits for society as a whole.

Another reason for preferring the for-whom conception over the by-whom conception concerns the fact that only the latter puts normative weight on the distinction between who does and who doesn’t fall under the extension of the relevant ‘scientific community’ (see §3.2). On the for-whom conception, progress does not depend on whether some relevant group of scientists — considered either as individuals or as a collective agent in its own right — change their cognitive attitudes on some way, so there is no need to delimit the extension of this group for the purposes of determining whether an episode is progressive. In so far as the distinction between ‘scientists’ and ‘non-scientists’ is relevant at all on the for-whom conception, it serves as a mere proxy for the distinction between those whose having access to a given piece of scientific information is more and less likely to lead them to make new discoveries on related topics, thus promoting future scientific progress. So while there is a sense in which even the for-whom conception emphasizes the importance of informing other scientists of scientific results,²⁷ the extension of ‘the scientific community’ plays no essential role on the for-whom conception in the way that it does on the by-whom conception.

One might point out, however, that although the for-whom conception places no normative weight on the distinction between ‘scientists’ and ‘non-scientists’, it does place normative weight on other distinctions that might be taken to be similarly arbitrary. In particular, given that the for-whom conception refers to ‘public information’, i.e. to information that is in principle accessible to any member of society, there is an indirect way in which the for-whom conception makes scientific progress depend on who does and who doesn’t belong to the relevant ‘society’. Indeed, I will not offer any precise definition of this term here; instead, I’ll leave it open whether it includes, for example, all and only the citizens of a particular nation, all of humanity, or something even more inclusive still. But this is not a problem in and of itself, for there is nothing problematic about having the normative issue of what constitutes scientific progress depend on the equally normative issue of who to count as members of the society for which progress is being made. If, for example, we were to identify ‘society’ with all of humanity, then it would seem natural and plausible to identify ‘scientific progress’ with changes in information that is ‘public’ in the sense of being in principle accessible to any human being.

Finally, let us also return briefly to Bird’s thought experiment of Dr N., who published his discovery in a reputable journal and later passed away along with everyone else who was aware of the discovery (see §3.1). It should be clear at this point that the for-whom conception counts Dr N.’s discovery as progressive throughout, since it plainly became public information upon being published in an academic journal and remained so

²⁷ There is no vicious circularity here, since the extent of progress made during one episode is not defined in terms of progress made during that same episode; but rather (partially) in terms whether progress is made during other, future episodes.

throughout the episode. This arguably accords with our unreflective judgment, i.e. our ‘intuition’, in this case (as Bird and Ross both in effect assume). By contrast, the by-whom conception — even on a collectivist version thereof — cannot unambiguously count this as a case of progress, since as we have seen the publication of Dr N.’s discovery is no guarantee that the scientific community has the requisite collective attitude. Similarly, in the modified Dr N.-case in which every member of the scientific community dies at time *t*, no version of the by-whom conception could plausibly claim that Dr N.’s discovery constitutes progress throughout, whereas the for-whom conception effortlessly counts it as progress in virtue of the continued public accessibility of Dr N.’s results in the *Journal of X-ology*.

Although I don’t myself consider ‘intuition’-based arguments of this sort to carry much argumentative weight in debates about scientific progress, this does suggest that the for-whom conception does not depart radically from a pre-theoretic concept of scientific progress (or, at any rate, less so than the by-whom conception). With that said, there may very well be other cases, yet to be discussed in the literature, in which it is less clear whether our ‘intuitions’ fit the for-whom conception better than the by-whom conception. Indeed, it would not surprise me if our unreflective judgments about scientific progress were so entangled with the by-whom conception that the latter seemed to us more ‘intuitive’ in many hypothetical cases. To the extent that this would turn out to be so, I would urge a revision of our pre-theoretic concept of scientific progress — away from a concept that focuses on scientists’ own cognitive attitudes, and toward a concept that focuses on accessibility of scientific information for the benefit of society as a whole. This ‘re-engineering’ would be motivated not by pre-theoretic judgments about hypothetical cases, but by our reflective judgements about what types of cognitive changes scientific research ought to aim to bring about.²⁸

5. Conclusion

I have argued that extant work on scientific progress has been in the grips of a mistaken conception about the role of cognitive attitudes in scientific progress. The implicit received view, the by-whom conception, holds that science progresses when the cognitive attitudes of scientists themselves — individually or collectively — improve in some specific way, e.g. by becoming more truthlike. This conception is problematic for several reasons, but most importantly because it cannot make good sense of why scientific progress should be valued by an entire society, as opposed to merely being valued by those whose cognitive attitudes supposedly improve in the process, viz. scientists themselves. In place of the by-whom conception, I have proposed an alternative, the for-whom conception, according to which scientific progress is determined by changes in public information, such as the content of academic journals, which makes it possible for various members of society — including scientists themselves, but not excluding all non-scientists — to improve their cognitive attitudes in some specific way, e.g. by becoming more truthlike.²⁹

References

American Association for the Advancement of Science. (2006). Statement on the teaching of evolution. Available at: <https://www.aaas.org/sites/default/files/0219boardstatement.pdf>.

²⁸ In this I follow the philosophical program variously known as ‘conceptual engineering’ (Cappelen, 2018), ‘conceptual ethics’ (Burgess & Plunkett, 2013a, b), or ‘ameliorative analysis’ (Haslanger, 2013).

²⁹ This paper was presented at the University of Wuppertal, Eindhoven University of Technology, and University of Zurich. I am very grateful to the audiences for insightful comments and discussions. I am even more grateful for written comments from Insa Lawler, James Norton, Anna Leuschner, and several anonymous reviewers. Research for this paper was supported by the Icelandic Research Fund (Grant 195617-051).

- Aronson, J. L., Harré, R., & Way, E. C. (1994). *Rescuing realism: How scientific progress is possible*. London: Duckworth.
- Bangu, S. (2015). Progress, understanding, and unification. In I. D. Toader, G. Sandu, & I. Parvu (Eds.), *Romanian studies in philosophy of science* (pp. 239–253). Springer.
- Barnes, E. (1991). Beyond verisimilitude: A linguistically invariant basis for scientific progress. *Synthese*, 88, 309–339.
- Bird, A. (2007). What is scientific progress? *Noûs*, 41, 64–89.
- Bird, A. (2008). Scientific progress as accumulation of knowledge: A reply to Rowbottom. *Studies in History and Philosophy of Science*, 39, 279–281.
- Bird, A. (2010). Social knowing: The social sense of 'scientific knowledge'. *Philosophical Perspectives*, 24, 23–56.
- Bird, A. (2014). When is there a group that knows? Distributed cognition, scientific knowledge, and the social epistemic subject. In J. Lackey (Ed.), *Essays in collective epistemology* (pp. 42–63). Oxford: Oxford University Press.
- Bird, A. (2016). Scientific progress. In *Oxford handbook in philosophy of science*. Oxford: Oxford University Press.
- Bird, A. (2019). The aim of belief and the aim of science. *Theoria: An International Journal for Theory, History and Foundations of Science*, 34, 171–193.
- Burgess, A., & Plunkett, D. (2013a). Conceptual ethics I. *Philosophy Compass*, 8, 1091–1001.
- Burgess, A., & Plunkett, D. (2013b). Conceptual ethics II. *Philosophy Compass*, 8, 1002–1010.
- Cappelen, H. (2018). *Fixing Language: An essay on conceptual engineering*. Oxford: Oxford University Press.
- Cevolani, G., & Tambolo, L. (2013). Progress as approximation to the truth: A defence of the verisimilitudinarian approach. *Erkenntnis*, 78, 921–935.
- Cohen, L. J. (1980). What has science to do with truth? *Synthese*, 45, 489–510.
- Dellsén, F. (2016). Scientific progress: Knowledge versus understanding. *Studies in History and Philosophy of Science*, 56, 72–83.
- Dellsén, F. (2018a). Scientific progress: Four accounts. *Philosophy Compass*, 13(11), Article e12525.
- Dellsén, F. (2018b). Scientific progress, understanding, and knowledge: Reply to Park. *Journal for General Philosophy of Science*, 49, 451–459.
- Dellsén, F. (2020). Beyond explanation: Understanding as dependency modeling. *The British Journal for the Philosophy of Science*, 71, 1261–1286.
- Dellsén, F. (2021). Understanding scientific progress: The noetic account. *Synthese*, 199, 11249–11278.
- Elgin, C. Z. (2017). *True enough*. Cambridge, MA: MIT Press.
- Gilbert, M. (1989). *On social facts*. London: Routledge.
- Gilbert, M. (1994). Remarks on collective belief. In F. Schmitt (Ed.), *Socializing epistemology: The social dimensions of knowledge* (pp. 235–256). Lanham, MD: Rowman and Littlefield.
- Gilbert, M. (2000). Collective belief and scientific change. In *Sociality and responsibility: New essays in plural subject theory* (pp. 37–49). Lanham, MD: Rowman and Littlefield.
- Haslanger, S. (2013). *Resisting reality: Social construction and social critique*. Oxford: Oxford University Press.
- Joint Statement. (2001). The science of climate change. *Science*, 292, 1261.
- Kaiser, M. (1996). Toward more secrecy in science? Comments on some structural changes in science-and on their implications for an ethics of science. *Perspectives on Science*, 4, 207–230.
- Khalifa, K. (2017). *Understanding, explanation, and scientific knowledge*. Cambridge: Cambridge University Press.
- Kitcher, P. (2011). *Science in a democratic society*. Oxford: Oxford University Press.
- Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.
- Kuhn, T. S. (1974). Second thoughts on paradigms. In F. Suppes (Ed.), *The structure of scientific theories* (pp. 459–482). Chicago, IL: University of Illinois Press.
- Kuipers, T. (2000). *From instrumentalism to constructive empiricism*. Dordrecht: Springer.
- Lackey, J. (2014). Socially extended knowledge. *Philosophical Issues*, 24, 282–298.
- Laudan, L. (1977). *Progress and its problems*. London: Routledge and Kegan Paul.
- Laudan, L. (1981). A problem-solving approach to scientific progress. In I. Hacking (Ed.), *Scientific revolutions* (pp. 144–155). Oxford: Oxford University Press.
- Laudan, L. (1984). *Science and values*. Berkeley, CA: University of California Press.
- Llewellyn Smith, C. (2015). Genesis of the large Hadron collider. *Philosophical Transactions of the Royal Society A*, 373, Article 20140037.
- Niiniluoto, I. (1980). Scientific progress. *Synthese*, 45, 427–462.
- Niiniluoto, I. (1984). *Is science progressive*. Dordrecht: Reidel.
- Niiniluoto, I. (1987). *Truthlikeness*. Dordrecht: D. Reidel.
- Niiniluoto, I. (1999). *Critical scientific realism*. Oxford: Clarendon Press.
- Niiniluoto, I. (2014). Scientific progress as increasing verisimilitude. *Studies in History and Philosophy of Science*, 46, 72–77.
- Niiniluoto, I. (2017). Optimistic realism about scientific progress. *Synthese*, 194, 3291–3309.
- Niiniluoto, I. (2019). Scientific progress. In E. N. Zalta (Ed.), *Stanford encyclopedia of philosophy*. Winter 2019 edition.
- Northcott, R. (2013). Verisimilitude: A causal approach. *Synthese*, 190, 1471–1488.
- Oddie, G. (1986). *Likeness to truth*. Dordrecht: D. Reidel.
- Park, S. (2017). Does scientific progress consist in increasing knowledge or understanding? *Journal for General Philosophy of Science*, 48, 569–579.
- Pettit, P. (2003). Groups with minds of their own. In A. I. Goldman, & D. Whitcomb (Eds.), *Social epistemology: Essential readings* (pp. 242–268). Oxford: Oxford University Press.
- Popper, K. R. (1963). *Conjectures and refutations: The growth of scientific knowledge*. London: Hutchinson.
- Popper, K. (1965). *Conjectures and refutations: The growth of scientific knowledge* (pp. 97–119). London: Routledge (chapter 3): Three Views Concerning Human Knowledge.
- Popper, K. R. (1979). *Objective knowledge: An evolutionary approach*. Oxford: Oxford University Press.
- Potochnik, A. (2015). The diverse aims of science. *Studies in History and Philosophy of Science*, 53, 71–80.
- Potochnik, A. (2017). *Idealization and the aims of science*. Chicago, IL: University of Chicago Press.
- de Regt, H. W. (2017). *Understanding scientific understanding*. Oxford: Oxford University Press.
- Ross, L. (2020). How intellectual communities progress. *Episteme*. <https://doi.org/10.1017/epi.2020.2>
- Rowbottom, D. P. (2008). N-rays and the semantic view of progress. *Studies in History and Philosophy of Science*, 39, 277–278.
- Rowbottom, D. P. (2015). Scientific progress without increasing verisimilitude: In response to Niiniluoto. *Studies In History and Philosophy of Science Part A*, 51, 100–104.
- Rowbottom, D. P. (2019). *The instrument of science: Scientific anti-realism revitalised*. London and New York: Routledge.
- Russell, B. (1919). *Introduction to mathematical philosophy*. London: Routledge.
- Schmitt, F. (1994). The justification of group beliefs. In F. Schmitt (Ed.), *Socializing epistemology: The social dimensions of knowledge* (pp. 257–287). Lanham, MD: Rowman and Littlefield.
- Solomon, M. (1996). Information and the ethics of information control in science. *Perspectives on Science*, 4, 195–206.
- Toumela, R. (1992). Group beliefs. *Synthese*, 91, 285–318.
- Toumela, R. (2004). Group knowledge analyzed. *Episteme*, 1, 109–127.
- Williamson, T. (2000). *Knowledge and its limits*. Oxford: Oxford University Press.