The Contemporary Scientific Progress Debate in Philosophy of Science and Empirical Evidence on *Knowledge That* versus *Knowledge How* in Scientific Practice

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Abstract: In his comprehensive survey of the contemporary debate over scientific progress in philosophy of science, Rowbottom observes that philosophers of science have mostly relied on interpretations of historical cases from the history of science and intuitions elicited by hypothetical cases as evidence for or against philosophical accounts of scientific progress. Only a few have tried to introduce empirical evidence into this debate, whereas most others have resisted the introduction of empirical evidence by claiming that doing so would reduce the debate to empirical studies of science. In this paper, I set out to show how empirical evidence can be introduced into the scientific progress debate. I conduct a corpus-based, quantitative study whose results suggest that there is a positive linear relationship between *knowledge that* talk and *knowledge how* talk in scientific articles. These results are contrary to Niiniluoto's view according to which there is a clear distinction between scientific progress and technological progress such that *knowledge that* belongs to the former, whereas *knowledge how* belongs to the latter.

Keywords: Darrell Rowbottom, empirical evidence, know how, knowledge that, metaphilosophy, scientific progress

1. Introduction

Darrell Rowbottom's *Scientific Progress* (2023) is a comprehensive review of the contemporary debate over scientific progress in philosophy of science. This is quite an impressive feat given that books in the Cambridge Elements series are meant to be succinct. Rowbottom manages to cover the major accounts of scientific progress in contemporary philosophy of science, including the epistemic, semantic, and noetic accounts, as well as critically examine central notions of the debate, such as notions of knowledge (e.g., *knowledge that* versus *knowledge how*) and the aim(s) of science (or lack thereof).

Rowbottom even touches on some of the metaphilosophical features of the contemporary scientific progress debate in philosophy of science. For instance, Rowbottom (2023) notes that "philosophers working on scientific progress have not adduced any empirical evidence showing the existence of collective aims" (p. 40) and that "authors on scientific progress [...] have done minimal empirical spadework to support their views of what (first-order) goodness makers [e.g., truth, knowledge, understanding, etc.] are" (p. 35). Rowbottom (2023) further observes that "This has only recently changed, with the work of Mizrahi" (p. 35), e.g., Mizrahi and Buckwalter (2014), Mizrahi (2021), and Mizrahi (2022a), but adds that "Most engaged in the debate do not take such [empirical] work to be relevant in telling for or against their views on progress" (p. 35).

Perhaps Rowbottom himself would welcome empirical work and empirical evidence playing an evidentiary role in the contemporary scientific progress debate. After all, Rowbottom (2023) develops a view of the aim(s) of science that "has a strong empirical component" (p. 43), which he takes to be an advantage of his view over Bird's (2022) view according to which functions underpin the aim(s) of science. Furthermore, Rowbottom (2023, p. 43) also says that "armchair thought about limited aspects of humans—their belief systems—does not seem to be an appropriate substitute for *the study of actual science*" (emphasis added).[1] In what follows, then, I set out to illustrate how empirical evidence can be relevant to the contemporary debate over scientific progress in philosophy of science by studying actual science.

At the outset, it is important to clear up a couple of seemingly pervasive misconceptions about the introduction of empirical evidence to philosophy of science in general and the contemporary scientific progress debate in particular. First, as Mizrahi (2021, p. 2382) is careful to point out in his empirical studies of conceptions of scientific progress in scientific practice, the results of such empirical studies "should not be interpreted as *conclusive evidence* for or against any philosophical account of scientific progress" (emphasis added). Yet, some philosophers of science often insist on rejecting empirical evidence as irrelevant to the debate over scientific progress in philosophy of science on the grounds that such evidence is inconclusive.

For instance, Niiniluoto (2024) claims that "Mizrahi's (2013) empirical observation that scientists talk about the aim of science in terms of knowledge rather than merely truth *cannot settle the philosophical debate* about scientific progress" (emphasis added). Of course, Mizrahi's empirical findings cannot *settle* the debate. For empirical evidence is not conclusive evidence. But that does not mean that empirical evidence has no role to play whatsoever in the debate. Empirical evidence can still play an evidentiary role in the debate either by lending some empirical support to one theory of scientific progress over another or by delineating the phenomena against which theories of scientific progress could be tested. Inconclusive evidence is still evidence that could be useful in ongoing debates. For instance, in the context of the ongoing debate over the cause of the Cretaceous-Paleogene mass extinction, the Chicxulub crater is not *conclusive* evidence for the asteroid impact hypothesis. The discovery of the Chicxulub crater in the Yucatán peninsula did not settle the debate. The debate is still going on. But it is still an important piece of evidence for that hypothesis (Chiarenza et al. 2020).

Moreover, it is apparent to anyone who is familiar with the contemporary scientific progress debate in philosophy of science that the evidence adduced by the methods philosophers of science have been using has not settled the debate (Mizrahi 2021, p. 2379). As Rowbottom (2023, p. 35) points out, "authors on scientific progress [...] typically use isolated case studies and thought experiments." The "contemporary debate about cognitive scientific progress usually proceeds," Rowbottom notes, by philosophers of science imagining "what scientists could have done differently in a historical scenario" (p. 1) or by conceiving "of a hypothetical situation where scientists face a dilemma and consider which choice would result in more progress" (p. 2). Philosophers of science have appealed to historical and hypothetical cases, even the same ones,

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[1] However, cf. Rowbottom (2019, p. 6) where he seems to agree with Niiniluoto (2024) that "the definition of progress should give us a normative standard for appraising the choices that the scientific communities have made, could have made, are just now making, and will make in the future. The task of finding and defending such standards is a genuinely philosophical one which can be enlightened by history and sociology but which *cannot be reduced to empirical studies of science*" (emphasis added). However, to advocate for empirical evidence playing an evidentiary role in the contemporary scientific progress debate in philosophy of science is *not* to reduce the debate to empirical studies of science. To present introducing empirical evidence into the debate as an all-or-nothing choice is to construct a false dichotomy. Adding an empirical dimension to the debate does not amount to reducing it to that dimension. I say more about that below. On the difference between empirically-informed philosophy of science and empirically-engaged philosophy of science, see Mizrahi (2022b, pp. 176-177).

to argue for competing accounts of scientific progress (Mizrahi 2022a, pp. 455-456). Clearly, then, such evidence has not settled the debate.[2]

Accordingly, if one were to deny empirical evidence any role whatsoever in the contemporary scientific progress debate on the grounds that such evidence cannot settle the debate, then one would have to reject evidence elicited by historical and hypothetical cases on precisely the same grounds as well. It is safe to assume that philosophers of science engaged in the scientific progress debate would not want to stop using interpretations of historical episodes and intuitions elicited by thought experiments as evidence in the contemporary scientific progress debate. Therefore, by modus tollens, it follows that they must not deny empirical evidence a role to play in the contemporary scientific progress debate solely on the grounds that such evidence cannot settle the debate.

Second, the use of empirical evidence does not preclude the use of other kinds of evidence, including evidence elicited by historical and hypothetical cases. In fact, by introducing other kinds of evidence into the debate, including empirical evidence, the debate might actually be "settled" insofar as a preponderance of evidence from multiple sources could favor one theory of scientific progress over another. After all, many philosophers of science generally agree that corroboration, i.e., when various pieces of evidence obtained by different means point to the same theory, is an epistemic good (Mizrahi 2020b, pp. 66-68). So, if it turns out that empirical evidence, intuitions elicited by thought experiments, and interpretations of episodes from the history of science all point to the same account of scientific progress, then that would be a welcome development in the contemporary scientific progress debate.

With these clarifications in mind, in what follows, I present empirical evidence that I think has some bearing on Rowbottom's (2023, pp. 20-21) discussion of *knowledge how* or *know-how*. Rowbottom discusses Mizrahi's (2013) proposal that the notion of scientific knowledge employed in the scientific progress debate should be expanded to include *knowledge how* in addition to *knowledge that*. As Rowbottom observes, some philosophers of science resist such an expansion of the notion of scientific knowledge. For instance, Niiniluoto (2024) objects that, if know-how increases were to count as scientific progress, then "the notion of scientific progress [would] in effect [be] reduced to science-based technological progress." This seems to suggest that, for Niiniluoto, there is a clear distinction between scientific progress and technological progress such that *knowledge that* belongs to the former, whereas *knowledge how* belongs to the latter (Niiniluoto 1984, pp. 258-266). As Niiniluoto (1984, p. 261) writes:

> While scientific progress is measured by *epistemic utilities* (such as truth, information content, truthlikeness, explanatory power, simplicity), technological progress is measured by *technological utilities* (effectiveness relative to a given practical purpose) (original emphasis).

If Niiniluoto is right about this clear distinction, then we would expect to see it manifested in scientific practice. More specifically, if *knowledge that* is "pure science" (Niiniluoto 1984, p. 265), whereas *knowledge how* is "applied science" or technology (Niiniluoto 1984, p. 260), and

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[2] For more on the methodological problems associated with using case studies from the history of science as evidence in philosophy of science, see Sauer and Scholl (2016, pp. 1-10), Bolinska and Martin (2020), (2021), and Mizrahi (2020a). For more on the methodological problems associated with appeals to intuition, see Mizrahi (2014), (2015), and (2022d).

the two are sharply and clearly distinct, as Niiniluoto seems to think (Niiniluoto 1984, pp. 258-266), then we would expect to find no relationship between talk of *knowledge that* and talk of *knowledge how* in scientific practice. Scientific practices, or scientific activities, which are what any "philosophical view of science is to be held accountable to" (van Fraassen 1994, p. 184), include "what scientists say and do" (Rouse 2007, p. 84). Accordingly, what practicing scientists say in academic articles published in scientific journals is part of scientific practices, or scientific activities, and thus part of what philosophical accounts of scientific progress are to be held accountable to.

For the purpose of this empirical study, then, my research question is this. Is there a relationship between talk of *knowledge that* and talk of *knowledge how* in academic articles written by practicing scientists and published in scientific journals? The null hypothesis is that there is no relationship between the two. The alternative hypothesis is that there is a relationship between talk of *knowledge that* and talk of *knowledge how* in academic articles written by practicing scientists and published in scientific journals. That is, if Niiniluoto is right, then we would expect to find no relationship between talk of *knowledge that* and talk of *knowledge how* in scientific publications, given that the two are clearly distinct and that scientific progress involves only increases in know-that, not know-how. But if, pace Niiniluoto, the notion of scientific knowledge is broad enough to include both *knowledge that* and *knowledge how*, then we would expect to find a relationship between talk of *knowledge that* and talk of *knowledge how* in scientific publications. Having articulated the research question and hypotheses to be tested, I now turn to discussing the methods of this empirical study, specifically, a corpus-based, quantitative study, in Section 2. After I discuss the methods in Section 2, I report the results of this empirical study in Section 3. In Section 4, I discuss what I take to be the broader implications of this empirical study for the contemporary scientific progress debate in philosophy of science.

2. Methods

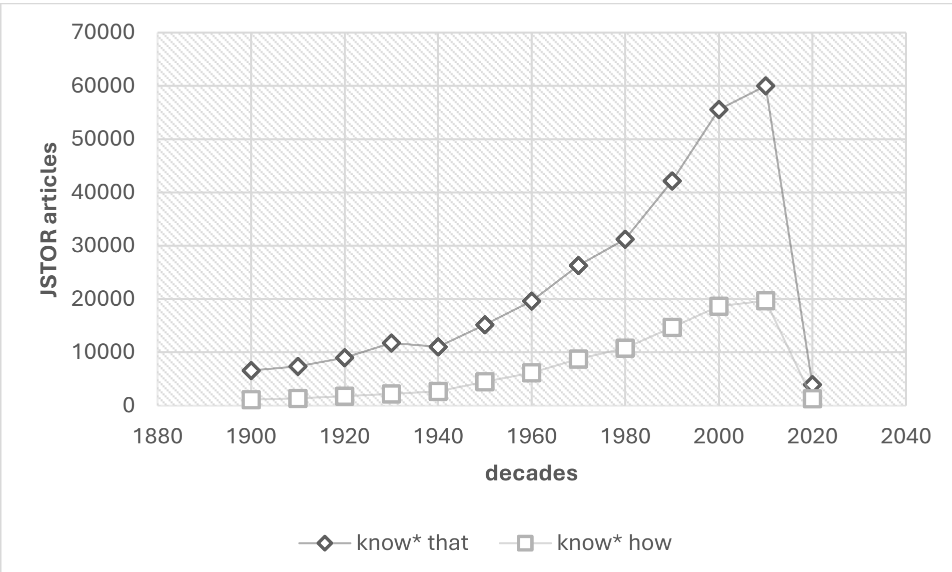
The data for this corpus-based, quantitative study were collected using the Constellate platform, specifically, the dataset builder feature on the Constellate platform (https://constellate.org/builder).[3] The dataset builder on the Constellate platform allows researchers to build datasets that consist of a collection of documents from various databases, such as the JSTOR and the Portico databases. For the purpose of this empirical study, I focused on journal articles written in English and published in scientific journals between the decades of 1900 and 2020 from the following categories in the JSTOR database:

- **Biological Sciences**: Agriculture, Biochemistry, Biogeography, Biology, Ecology, and Paleontology
- **Physical Sciences**: Astronomy, Chemistry, Earth Sciences, Materials Science, and Physics
- **Social Sciences**: Anthropology, Archaeology, Behavioral Sciences, Communications, Food Studies, Human Geography, Population Studies, Psychology, and Sociology[4]

[3] Unfortunately, ITHAKA decided to sunset Constellate on July 1, 2025. The announcement can be read here: https://constellate.org/docs/constellate-sunset?ref=cms-prod.constellate.org.
[4] See Pence and Ramsey (2018) on digital philosophy of science and how to use data from JSTOR.

Using these search parameters, I created two datasets from articles in the JSTOR database. The first dataset is the “know* that” dataset for scientific articles in English from the Biological Sciences, Physical Sciences, and Social Sciences categories, published in scientific journals between the decades of 1900 and 2020, which contain the phrases “know that,” “known that,” “knowing that,” and “knowledge that.” The second dataset is the “know* how” dataset for scientific articles in English from the Biological Sciences, Physical Sciences, and Social Sciences categories, published in scientific journals between the decades of 1900 and 2020, which contain the phrases “know how,” “known how,” “knowing how,” and “knowledge how.” See Figure 1.[5]

Figure 1. Article counts for the “know* that” and “know* how” datasets by decade from 1900 to 2020 in the Biological Sciences, Physical Sciences, and Social Sciences categories of the JSTOR database



To address the concern that any relationship between “know* that” and “know* how” in scientific articles may be a feature of the JSTOR database itself rather than *knowledge that* and *knowledge how* talk in scientific articles, I run similar searches on scientific articles from the Portico database using the Constellate platform as well. In the Portico database, the categories are as follows:

- **Biological Sciences**: Agriculture, Biochemistry, Biogeography, Biology, Ecology, and Paleontology
- **Physical Sciences**: Astronomy, Chemistry, Earth Sciences, Materials Science, Metrology, and Physics

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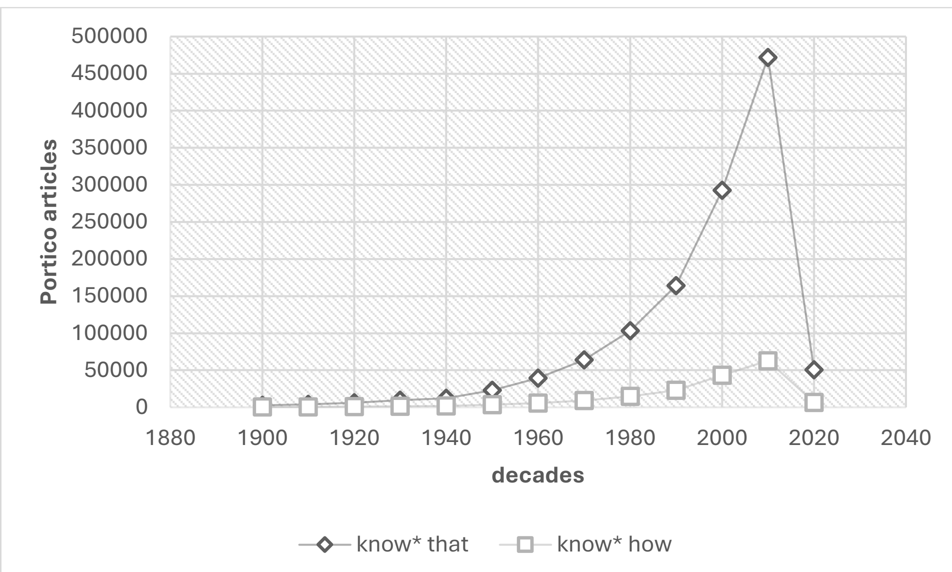
[5] In the search syntax of the Constellate platform, an * at the end of a term signifies a prefix query (https://constellate.org/docs/how-the-search-engine-works). Accordingly, searching for “know*” will turn up results that include “know,” “known,” “knowing,” and “knowledge.” However, exact search phrasing and wildcard searching cannot be performed simultaneously within the same search query using the ElasticSearch engine (https://www.elastic.co/guide/en/elasticsearch/reference/current/search-your-data.html). To overcome this obstacle, I run searches of “know that,” “known that,” “knowing that,” and “knowledge that” separately and then combined the search results. I did the same for “know how,” “known how,” “knowing how,” and “knowledge how.”

- **Social Sciences**: Anthropology, Archaeology, Behavioral Sciences, Communications, Food Studies, Human Geography, Population Studies, Psychology, Sociology, and Urban Studies

Using similar search parameters, I created two datasets from articles in the Portico database. The first dataset is the “know* that” dataset for scientific articles in English from the Biological Sciences, Physical Sciences, and Social Sciences categories, published in scientific journals between the decades of 1900 and 2020, which contain the phrases “know that,” “known that,” “knowing that,” and “knowledge that.” The second dataset is the “know* how” dataset for scientific articles in English from the Biological Sciences, Physical Sciences, and Social Sciences categories, published in scientific journals between the decades of 1900 and 2020, which contain the phrases “know how,” “known how,” “knowing how,” and “knowledge how.” See Figure 2.

Figure 2. Article counts for the “know* that” and “know* how” datasets by decade from 1900 to 2020 in the Biological Sciences, Physical Sciences, and Social Sciences categories of the Portico database



Recall that the research question for this empirical study is whether there is a relationship between talk of *knowledge that* and talk of *knowledge how* in academic articles written by practicing scientists and published in scientific journals. On the one hand, if we find a relationship between the article counts of the “know* that” datasets and the article counts of the “know* how” datasets, then that would suggest an affirmative answer to the research question. On the other hand, if we find no relationship between the article counts of the “know* that” datasets and the article counts of the “know* how” datasets, then that would suggest a negative answer to the research question.

In other words, Niiniluoto seems to sharply draw a clear distinction between scientific progress and technological progress such that *knowledge that* is “pure science,” whereas *knowledge how* is “applied science” or technology. If Niiniluoto is right about there being such a clear distinction between “pure science” as *knowledge that* and “applied science” or technology as *knowledge how*, then we would expect to find no relationship between talk of *knowledge that* and talk of *knowledge how* in scientific articles, which would be indicated by a lack of any relationship between the number of “know* that” articles and the number of “know* how” articles. This is the null hypothesis. But if we do find a relationship between the number of “know* that” articles and the number of “know* how” articles, which would indicate that there is a relationship between talk of *knowledge that* and talk of *knowledge how* in scientific articles, then that would suggest that, pace Niiniluoto, there is no clear distinction between scientific progress and technological progress, such that *knowledge that* is “pure science,” whereas *knowledge how* is “applied science” or technology. This is the alternative hypothesis.

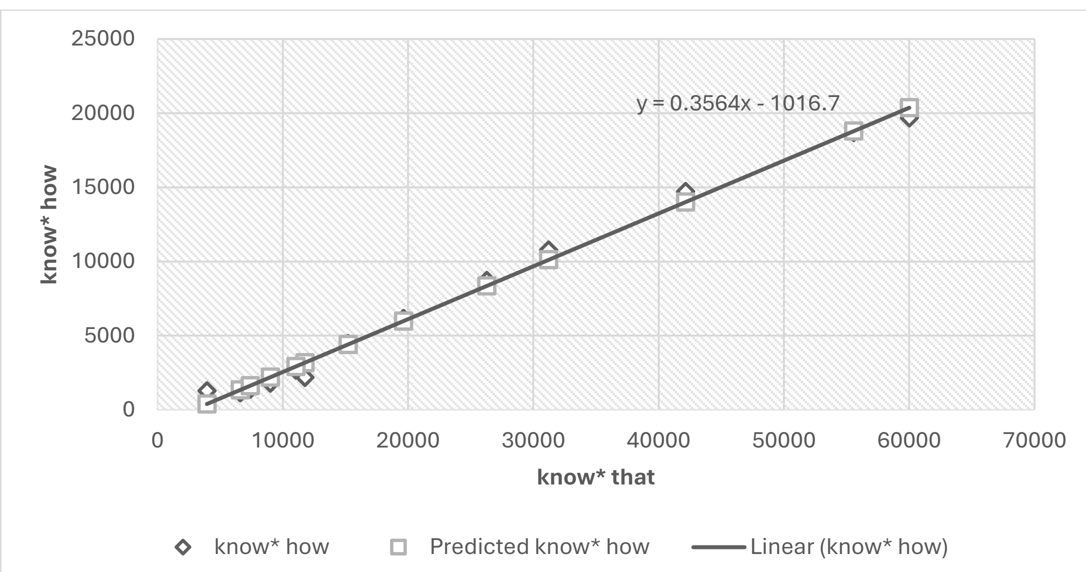
Having explained the methods, I now turn to discussing the results of this empirical study in Section 3. In Section 4, I discuss what I take to be the broader implications of this empirical study for the contemporary scientific progress debate in philosophy of science.

3. Results

To find out if there is a relationship between the number of “know* that” articles and the number of “know* how” articles published in scientific journals between the decades of 1900 and 2020 from the JSTOR database, I conducted a couple of statistical analyses. First, I performed a Pearson correlation analysis to find out if there is a correlation between the number of “know* that” articles and the number of “know* how” articles. A Pearson correlation analysis revealed a strong positive correlation between “know* that” and “know* how” article counts, $r(11) = 0.99$, $p < 0.01$.

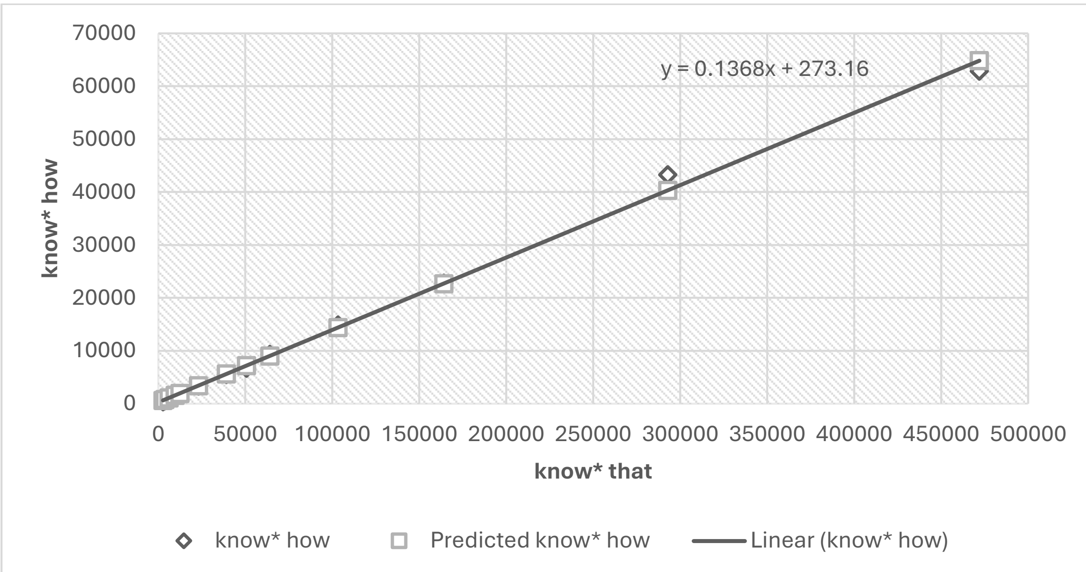
Since a Pearson correlation analysis indicated a strong positive correlation between “know* that” and “know* how” article counts, I also performed a simple linear regression analysis. A statistically significant regression equation was found, $F(1,11) = 1644.53$, $p < 0.01$, with an R^2 of 0.99. This means that 99% of the variance in “know* how” article counts is explained by “know* that” article counts. See Figure 3.

Figure 3. Linear relationship between “know* that” and “know* how” article counts from the JSTOR database



Similar results were obtained from the datasets of the Portico database. A Pearson correlation analysis revealed a strong positive correlation between "know* that" and "know* how" article counts, $r(11) = 0.99$, $p < 0.01$. Moreover, a simple linear regression analysis revealed a statistically significant regression equation, $F(1,11) = 3536.33$, $p < 0.01$, with an R^2 of 0.99. This means that 99% of the variance in "know* how" article counts is explained by "know* that" article counts. See Figure 4.

Figure 4. Linear relationship between "know* that" and "know* how" article counts from the Portico database



To verify that the search methodology described in Section 2 returns results of *knowledge that* talk and *knowledge how* talk in academic articles written by practicing scientists and published in scientific journals, I curated four examples of *knowledge that* and *knowledge how* talk in scientific articles.

"know* that" datasets (emphasis added):

1. "Observationally we *know that* the galaxy population looked different in the past" (Conselice 2000, p. 285).
2. "ever since the 1970s we have *known that* the strong nuclear forces between neutrons and protons, collectively known as nucleons, are ultimately governed by quantum chromodynamics (QCD)" (Schäfer and Baym 2021, p. 1).
3. "*Knowing that* $p(500)$ has 22 digits, we set $E = 70$, $L = 100$, and attenuation = 0.9 (since $(0.9)^{500} \approx 10^{-23}$" (Dubner 1992, p. 733).
4. "It starts by unpacking the meaning of powerful knowledge, and then uses the conclusions of the analysis to identify and describe types of geographical *knowledge that* might be considered powerful" (Maude 2016, p 70).

"know* how" datasets (emphasis added):

1. "We *know how* smooth flows enable mixing but less well the manner in which a turbulent flow influences it" (Sreenivasan 2019, p. 18175).

2. “While it is well *known how* they affect the feeding preferences of aboveground herbivores, this information is lacking for soil ecosystems, where examining plant-herbivore trophic interactions is difficult” (Schallhart et al. 2012, p. 2650).
3. “Moreover, *knowing how* the process of bioturbation proceeds in the vertical dimension may permit interpretation of contacts between beds and may shed further light on depositional processes” (Clifton and Hunter 1973, p. 259).
4. “Thus, it seems we possess the *knowledge how* to measure children’s SWB and it is time to look beyond the measurement issue so we can better understand what affects children’s SWB as well as its implications” (Dinisman and Ben-Arieh 2016, p. 556).

To be clear, these examples are not meant to play an evidentiary role in this study. They are provided here merely as a verification measure of the search methodology described in Section 2. The empirical evidence of this empirical study consists in the results of the aforementioned statistical analyses.

To sum up, the results of Pearson correlation analyses indicate that the number of “know* that” articles and the number of “know* how” articles published in scientific journals between the decades of 1900 and 2020 are strongly positively correlated. In addition, the results of simple linear regression analyses reveal that there is a positive linear relationship between “know* that” and “know* how” article counts. These results were obtained from data mined from the JSTOR database and the Portico database using the Constellate platform. Overall, these results suggest that we should reject the null hypothesis according to which there is no relationship between talk of *knowledge that* and talk of *knowledge how* in scientific articles and instead accept the alternative hypothesis according to which there is a relationship, specifically, a positive linear relationship, between the two.

These results are *not* what we would expect to find if, as Niiniluoto seems to think, there were a clear distinction between scientific progress and technological progress such that *knowledge that* is “pure science,” whereas *knowledge how* is “applied science” or technology. That is, if there were a clear distinction between *knowledge that* talk, which indicated scientific progress, and *knowledge how* talk, which indicated technological progress, as Niiniluoto seems to think, then we would expect to find no relationship between *knowledge that* and *knowledge how* talk in scientific articles. Instead, what we find, as indicated by the results of this empirical study, is that there is a positive linear relationship between *knowledge that* and *knowledge how* talk in scientific articles. In other words, the more scientists talk about *knowing that*, the more they also talk about *knowing how* in scientific articles.

Having reported the results, I now turn to discussing what I take to be the broader implications of this empirical study for the contemporary scientific progress debate in philosophy of science.

4. Discussion

In his comprehensive survey of the contemporary debate over scientific progress in philosophy of science, Rowbottom (2023, p. 35) observes that philosophers of science have mostly relied on interpretations of historical cases from the history of science and intuitions elicited by hypothetical cases as evidence for or against philosophical accounts of scientific progress. Only a few philosophers of science engaged in the scientific progress debate, such as Mizrahi and Buckwalter (2014), Mizrahi (2021), and Mizrahi (2022a), have tried to introduce empirical evidence into this debate, whereas most others have resisted the introduction of empirical evidence into the debate by claiming that doing so would reduce the debate to empirical studies of science (Niiniluoto 2024).

In this paper, I set out to show how empirical evidence can be introduced into the contemporary scientific progress debate in philosophy of science. I have presented empirical evidence suggesting that there is a positive linear relationship between *knowledge that* and *knowledge how* talk in scientific articles. In doing so, I have not reduced the debate to empirical studies of science, pace Niiniluoto (2024). To use empirical evidence in the contemporary scientific progress debate in philosophy of science is *not* to reduce the debate to empirical studies of science any more than using computational techniques to model the behavior of subatomic particles is to reduce particle physics to computer science. To claim otherwise, and to present introducing empirical evidence into the debate as an all-or-nothing choice, is to construct a false dichotomy.[6] Empirical evidence can play an evidentiary role in the scientific progress debate alongside other kinds of evidence, including the kinds of evidence philosophers of science engaged in the scientific progress debate typically use, i.e., the sort of evidence that can be gleaned from “isolated case studies and thought experiments” (Rowbottom 2023, p. 35).

According to Machery (2016, p. 480), “If we can show experimentally that a candidate rational reconstruction of a given concept *x* has nothing or little to do with scientists’ unreconstructed use of *x*, then this gives us a strong reason to assume that the reconstruction is erroneous.” In other words, the ways in which practicing scientists use concepts, such as *knowledge that* and *knowledge how*, can serve as evidence against which philosophical accounts of science can be tested empirically. If we find that a philosophical account of a scientific concept diverges widely from the ways in which practicing scientists employ a concept, that does not necessarily mean that we should reject that philosophical account. For empirical evidence is not conclusive evidence (see Section 1). But if we do find that a philosophical account of a scientific concept diverges widely from the ways in which practicing scientists employ that concept, then, at the very least, proponents of that philosophical account owe us an explanation as to why that is the case.

As we have seen, the results of this empirical study suggest that there is a positive linear relationship between *knowledge that* and *knowledge how* talk in academic articles written by practicing scientists and published in scientific journals. That is, the more scientists talk about *knowing that*, the more they also talk about *knowing how* in scientific articles. So, if Niiniluoto wants to insist that we should sharply and clearly distinguish between *knowledge that* talk, which indicates scientific progress, and *knowledge how* talk, which indicates technological progress, then, at the very least, he owes us an explanation as to why practicing scientists do not seem to respect such a clear distinction between *knowledge that* and *knowledge how* in their scientific articles.

At this point, Niiniluoto could appeal to the distinction between the context of discovery and the context of justification, and then insist that philosophers of science should only be interested in what science *ought to be*, not what science actually *is*. This would mean that

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[6] Attempts to incorporate empirical or experimental methods into philosophy have often been met with the “that’s not philosophy” (Jenkins 2014) or “that’s not philosophically significant” charge. See, e.g., Kauppinen (2007). Cf. Knobe (2007); O’Neill and Machery (2014). See also Mizrahi (2022c, pp. 187-191).

philosophy of science's object of study is *ideal science*, by means of rational reconstructions (Mizrahi 2020c), not *actual science*. As Seo and Chang (2015) put it:

> Discovery is a subject of all kinds of empirical research, historical, sociological, and psychological. Epistemology is and should be confined to the "context of justification," in which the propositions produced in science are reformulated and rearranged so that their structures and logical relations are made explicit. *Epistemology thus considers a rational reconstruction of scientific practice, rather than the actual practice of scientists* (emphasis added).

I leave it to readers to judge whether philosophy of science is in the business of studying ideal science or actual science. But note that, for Rowbottom (2023, p. 43), "armchair thought about limited aspects of humans—their belief systems—does not seem to be an appropriate substitute for *the study of actual science*" (emphasis added).

Besides, why not both? After all, there seems to be no reason why philosophy of science cannot be a methodologically interdisciplinary academic discipline that employs a variety of methods, including empirical methods, to study both ideal science and actual science. Let a thousand methodological flowers bloom! For instance, Poliseli and Russo (2022) point out that the Society for Philosophy of Science in Practice (SPSP) advocates for the study of scientific practices in methodologically diverse ways. As Poliseli and Russo (2022, p. 111) put it:

> [Philosophy of Science in Practice] does not possess any general protocol or any specific methodology to apply in order to achieve its goals. The instruments used to investigate the practices of the sciences come from history, psychology, technology studies, sociology, and so on. These instruments include, but are not limited to, conceptual analysis, historical reconstruction and contextualization, analysis and consideration of cultural, social, political aspects, discourse analysis, formal methods, or ethnographic approaches.

Indeed, the empirical methods of the sciences seem to be especially suited for studying actual scientific practices or activities. According to the mission statement of the Society for Philosophy of Science in Practice (2006-2025), "Practice consists of organized or regulated activities aimed at the achievement of certain goals. Therefore, the epistemology of [scientific] practice must elucidate what kinds of activities are required in generating [scientific] knowledge." It is difficult to see how philosophers of science can study actual scientific practices or activities by reflecting upon them from their armchairs. To study actual scientific practices or activities, philosophers of science must *observe* those practices or activities, which is to study them empirically. To borrow a phrase from Wittgenstein, the philosopher of science in practice must *look and see* what scientific practitioners actually *say* and *do* (Mizrahi 2022b, pp. 167-186).

In his discussion of extending the epistemic account of scientific progress to include know-how, Rowbottom considers the possibility that increases in scientific *knowledge how* promote, but do not constitute, scientific progress. As Rowbottom (2023, p. 21) puts it:

> One line of counterargument [Mizrahi (2013)] does not consider, however, is that increases in *know-how* only promote, but do not constitute, progress. In other words, developing new instruments like MRI scanners, and new techniques like gene splicing,

might enable (or increase the probability of) the attainment of new cognitive goods – for example, new *knowledge that* – without *being* cognitively good (original emphasis).

As I understand it, Rowbottom entertains the possibility that *knowledge that* has intrinsic value as an epistemic good of science, whereas *knowledge how* only has instrumental value as a means to an end (where the end goal of science is *knowledge that*) as a counterargument against the enhanced epistemic view. According to the enhanced epistemic account, scientific progress consists in accumulating scientific knowledge, where scientific knowledge includes theoretical and empirical *knowledge that* as well as methodological and practical *knowledge how* (Mizrahi 2013).

Of course, it is possible that *knowledge that* has intrinsic value, whereas *knowledge how* only has instrumental value as far as scientific progress is concerned. More importantly, I submit, this hypothesis can be tested empirically. Using survey methodologies, for instance, we can ask practicing scientists whether they value *knowledge how* merely as an instrument for getting *knowledge that*, whether they value increases in know-how intrinsically, whether they assign more worth to know-that over know-how as far as making progress in their field is concerned, and so on (see, e.g., Beebe and Dellsén 2020).

A cursory look at actual scientific practices or activities, i.e., "what scientists say and do" (Rouse 2007, p. 84), would suggest that practicing scientists do value know-how insofar as they reward scientists whose work leads to increases in know-how with one of the most prestigious awards, namely, the Nobel Prize (Mizrahi 2013). For example, in 1939, Ernest Orlando Lawrence was awarded the Nobel Prize in Physics "for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements" (Nobel Prize Outreach 2025). Awarding a scientist for inventing a scientific instrument (methodological knowledge) that can be used to obtain results (empirical knowledge) is a rather strong indication that knowing how to use this scientific instrument to study particles is valued for its own sake.

In fact, insofar as *knowledge how*, such as the know-how gained by the invention of the cyclotron, could lead to new avenues of scientific research, it could be argued that methodological know-how may be as valuable as theoretical know-that, if not more so, given that *fruitfulness* or *fecundity* is considered a theoretical virtue by many philosophers of science (Mizrahi 2022e). Nonetheless, as Rowbottom rightly points out, it is still possible that scientists might consider the know-how of the cyclotron to be less valuable than the know-that it made possible. So, a more systematic study of the attitudes of practicing scientists toward know-that and know-how is needed. Since space is limited here, I leave this question to future studies.

Niiniluoto would likely object that surveying the attitudes of practicing scientists could tell us nothing about scientific progress. As Rowbottom (2023, p. 20) notes, "A standard criticism of Mizrahi's (2013) approach is that scientists' opinions are not good indicators of what scientific progress consists in." But if what practicing scientists say about progress in their scientific fields is not good evidence for what counts as progress in those fields, then what professional philosophers say about progress in academic philosophy is not good evidence for what counts as progress in academic philosophy, what official diplomats say about progress in diplomatic negotiations is not good evidence for what counts as progress in diplomatic negotiations, what construction managers say about progress in construction projects is not good evidence for what counts as progress in construction projects, and so on. We would need extraordinarily good reasons to believe that professional practitioners are not good judges of progress in their own fields of practice (Mizrahi 2013, pp. 386-387). In the absence of such extraordinary evidence, we can conclude by modus tollens that what practicing scientists say about progress in their scientific fields is good (albeit *not* conclusive) evidence for what counts as progress in those fields.

5. Conclusion

In his comprehensive survey of the contemporary debate over scientific progress in philosophy of science, Rowbottom (2023, p. 35) observes that philosophers of science have mostly relied on interpretations of historical cases from the history of science and intuitions elicited by hypothetical cases as evidence for or against philosophical accounts of scientific progress. Only a few philosophers of science engaged in the scientific progress debate, such as Mizrahi and Buckwalter (2014), Mizrahi (2021), and Mizrahi (2022a), have tried to introduce empirical evidence into this debate, whereas most others have resisted the introduction of empirical evidence into the debate by claiming that doing so would reduce the debate to empirical studies of science (Niiniluoto 2024).

In this paper, I set out to show how empirical evidence can be introduced into the contemporary scientific progress debate in philosophy of science. I have presented empirical evidence suggesting that there is a positive linear relationship between *knowledge that* and *knowledge how* talk in scientific articles. I have also discussed what I take to be the broader implications of this empirical study. In particular, I have argued that empirical evidence can play an evidentiary role in the scientific progress debate alongside other kinds of evidence, including the kinds of evidence philosophers of science engaged in the scientific progress debate typically use, i.e., the sort of evidence that can be gleaned from “isolated case studies and thought experiments” (Rowbottom 2023, p. 35).

In the absence of commonly accepted research practices and methods, the introduction of new methods into academic philosophy of science is not only desirable but also reasonable, especially methods with a track record of success, such as the track record of the empirical methods of the sciences (Mizrahi 2022c). That is, academic philosophy of science can be considered an immature rather than a mature academic discipline. Mature academic disciplines are “based upon conceptually integrated paradigms, commonly accepted research practices, standardized problem definitions, canonized exemplary solutions, and binding types of theoretical explanations.” On the other hand, “the more diffuse, personalized, and idiosyncratic are the standards of epistemic legitimacy,” the more likely an academic discipline is to be viewed as immature (Fuchs and Turner 1986, p. 148). Insofar as academic philosophy of science does not have “conceptually integrated paradigms, commonly accepted research practices, standardized problem definitions, canonized exemplary solutions, and binding types of theoretical explanations” (Fuchs and Turner 1986, p. 148), it cannot be considered a mature academic discipline. Likewise, insofar as its standards of epistemic legitimacy depend in large part on personalized interpretations of historical cases and idiosyncratic intuitions elicited by hypothetical cases, academic philosophy of science cannot be considered a mature academic discipline. As such, academic philosophy of science could become a more mature academic discipline by the introduction of methods with a track record of success, such as the methods of the empirical sciences, into its key debates, such as the contemporary debate over scientific progress.

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