The Scientific Instrument: The Case for Constructive Empiricism over Scientific Realism

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Instrumentalism is the best way to explain how science works. Although many career scientists tend to identify themselves as scientific realists, they fail to see the pitfalls of this metaphysical commitment. Karl Popper tried to solve these problems, but his account of how science works is ultimately unsatisfactory, and his arguments against instrumentalism are unconvincing. Instrumentalists themselves hold a wide variety of beliefs, but one of the most salient instrumentalist positions comes from Bas van Fraassen with his emphasis on an agnostic attitude toward theoretical entities and his pragmatic approach which he labeled constructive empiricism. This modern theory of scientific instrumentalism, with some minor adjustments, is robust enough to withstand the criticisms that plague the realists, and explanatory enough to reflect how science is actually done, which mirrors how it is taught in the classroom. Modern scientists may claim that they are realists, but they ought to realize that a more defensible and efficacious position for them to take is that of scientific instrumentalism.

The Logical Dilemma of Science

Scientific disciplines are in many ways distinct from their counterparts in the humanities. For one thing, it can be said of science that it is, and has been for millennia, characterized by a certain "success". Though what is actually meant by the term success here may be somewhat nebulous, it is quite easy to look around and take note of the technological advancements that tell of a vastly increased understanding compared to that of our forebears. What could be the cause of all of these advancements in understanding but the enterprise and scholastic discipline of science? Yet, as philosophers of science, we recognize that it is not enough for us to simply resign ourselves to that fact that science "just works". We must delve deeper into the epistemological (concerning what we *know*) and metaphysical (concerning what *actually* is) underpinnings of science if we are to account for its successes.

Most career scientists, today as well as throughout history, when asked would identify themselves as *scientific realists*. That is to say, they believe not only that the theories that comprise the scientific canon are true, but also that the entities which they describe actually exist. This position seems to be a reasonable one, given the successful track record of empirical science. Why shouldn't we believe that the constituent theories of science are actually true? Upon further investigation, however, we find that this realist worldview is not without its problems.

One of the most serious obstacles to the belief that our theories are actually true is David Hume's problem of induction. To outline the problem, Hume pointed out that there are two ways in which we can reason: deductive and inductive. Deductive reasoning forms arguments in which the conclusion logically follows from the premises, and inductive reasoning allows us to form arguments that support the conclusion, but do not *guarantee* it. The problem of induction has to do with how we should go about proving that inductive logic is reliable. We are left with a choice of begging the question by inductively arguing for the reliability of induction, or of formulating a deductive argument which contains as a premise the conclusion we wish to reach, namely, that inductive reasoning is reliable.[1] This issue is particularly problematic for the scientific realist, because the way he goes about gathering knowledge is by using the empirical scientific method, which necessarily employs inductive reasoning in its extrapolation of data to universal laws.

Addressing the Logical Dilemma

Karl Popper, by advancing his theory of critical rationalism, hoped to solve this and other problems put to scientific realism by skeptics like Hume. Popper describes his critical rationalism as a theory of knowledge that consists in *conjectures and refutations*, and claims that the only type of knowledge that is accessible to the human mind is hypothetical or conjectural knowledge.[2] Despite Popper's disagreement with Hume's skepticism, calling it a surrender to irrationality, he takes Hume's problem of induction quite seriously. He addresses the problem in the following way:

> The answer to this problem is: as implied by Hume, we certainly are not justified in reasoning from am instance to the truth

[1] Alex Rosenberg, *Philosophy of Science: A Contemporary Introduction* (New York: Routledge, 2012) 181-82.

[2] Karl. R. Popper, "From *The Beginnings of Rationalism,*" in *Popper Selections,* ed. David Miller, (Princeton: Princeton University Press, 1985), 30.

> of the corresponding law. But to this negative result a second result, equally negative, may be added: we *are* justified in reasoning from a counterinstance to the *falsity* of the corresponding universal law (that is, of any law of which it is a counterinstance).[3]

Thus, Popper shows that we are safe in making inferences that use specific instances to *falsify* universal laws because that process is deductively valid. He develops his entire theory of science around the practice of falsification, and ultimately makes the claim that it is the scientist's duty to "search for and test the most far-flung empirical consequences of [his] laws and theories".[4]

While Popper may have done a good deal of work in order to avoid the mire of the problem of induction, his theory of critical rationalism leaves huge gaps in the explanation of how science actually works. It may be an adequate notion, that scientists create hypotheses and seek only to falsify them and that falsified theories are of no use to the canon of science, but this process simply isn't reflected by the actual nature of science as an enterprise. There are many historical examples that haven't quite played out the way it seems Popper would have liked them to, and not too many people seem to mind. One glaring example is the persistence of Newtonian physics in the science classrooms. For over a century we've known that Newton's theories about masses, forces, and their interactions were, at best, incomplete. Since then we've adopted two new theories of mechanics, relativistic and quantum. But despite its having been proven over and over again to be technically incorrect, Newtonian theory is still taught today and is used in a wide variety of applications by career scientists. What seems to account for instances like this, where a theory is maintained in spite of its failure to satisfy the logical requirements of critical rationalism, is a theory of *scientific instrumentalism*.

Grappling with Instrumentalism

Throughout the history of the philosophy of science, there have been many different incarnations of what is now called instrumentalism. Though they vary on some of the finer points, the main theme of all instrumentalist theories is the assertion that our scientific laws are nothing more than special tools that we have constructed in order to understand the world, and that they need not describe things that actually exist, or events that actually occur (in the metaphysical sense). Instrumentalism is a certain breed of anti-realism in that it detaches itself from the necessity of metaphysical truth altogether, instead placing emphasis on empirical success for its ability to discern between good and bad scientific theories.[5] Popper was aware of the prospects of instrumentalism, and gave extensive arguments against the theories of instrumentalism which had already pervaded in the philosophy of science before him.

In his seminal work, *Conjectures and Refutations*, Popper offers an overview of the instrumentalist argument, and describes his grievances against it. The biggest clash between Popper and the instrumentalists is that, according to the instrumentalist agenda, "for instrumental purposes of practical application a theory may continue to be used *even after its refutation*, within the limits of its applicability,"[6] which is directly opposite of Popper's heuristic of falsification. Popper's conception of science, and of scientific progress, only holds together if we stick to the program of falsifying our theories in favor of new and equally falsifiable hypotheses.

Popper's complaint that "instruments, even theories *in so far as they are instruments*, cannot be refuted,"[7] is one that attempts to cast instrumentalism out of the realm of science by Popper's own criterion of falsifiability. His worry is that if we are simply bound to amend a scientific theory *ad hoc*, or to rearrange the borders of a theory's application in order to preserve it from being falsified by empirical data, then all theory will lose meaning, and science could not be said to exhibit any sort of positive progress. He also disparages the instrumentalist mindset as one that is fundamentally inferior with regard to its concept of the role of science. Popper speaks of a "highly critical attitude requisite in the pure scientist" as a noble search for truth and falsity, and casts the instrumentalist down as one who is merely complacent with the success of applications.[8]

Popper's complaints are, however, either largely uncharitable to the instrumentalist's conception of science, or unconvincing simply because they beg the question of his own account of scientific realism. His worries that instrumental science will devolve into an incoherent collection of

[3] Karl. R. Popper, "From *The Problem of Induction,*" in *Popper Selections,* ed. David Miller, (Princeton: Princeton University Press, 1985), 110.

[4] Arthur Fine, "The Scientific Image Twenty Years Later," *Philosophical Studies* 106 (2001): 109.

[5] Gary Gutting, "Scientific Realism versus Constructive Empiricism: A Dialogue," in *Philosophy of Science: Contemporary Readings,* ed. Yuri Balashov and Alex Rosenberg (New York: Routledge, 2002), 239.

[6] Karl R. Popper, *Conjectures and Refutations* (London: Routledge and Kegan Paul, 1963), 113.

[7] —.113.

[8] —.114.

arbitrary definitions and rules assumes that the instrumentalists excluded from their epistemic system any notion of theory choice, which of course they did not. The famous French instrumentalists Pierre Duhem and Henri Poincaré both employed methodologies which placed a great deal of emphasis on *unity* and *simplicity* as criteria for theory choice.[9] In fact, this consideration is common to nearly all instrumentalist accounts of science, and turns out to be a perfectly adequate way to enforce the non-arbitrariness of our scientific theories. And lastly, Popper's complaint that instrumentalism in some way adulterates the scientific discipline by denying the search for truth comes from a presupposition that science need be concerned with such truth to be meaningful. A more charitable understanding of the instrumentalist point of view on Popper's part would have led him to see that instrumentalists, rather than just doing away with the idea of a scientific aim, are simply skeptical of the claim that such an aim ought to be truth itself.

It seems, then, that Popper has ultimately lost the realist/instrumentalist debate jointly due to the more successful description by instrumentalists of how science actually works, and Popper's own inability to conclusively demonstrate the superiority of critical rationalism. In addition to the persistence of Newtonian physics, there are multiple examples of how science has made leaps and bounds while simultaneously ignoring Popper's strictures of falsification. Some examples occur on the cusp of scientific revolution, like the way in which Einstein was able to predict quantitatively how the light of a star could be seen to curve around the sun during a solar eclipse. Einstein's predictions turned out to be so accurate that this instance of confirmation played a significant role in the adoption of his theory of relativity, despite Popper's admonition that theories can only be falsified and never confirmed.[10] The reason Einstein's predictions matter is that they constitute a paradigm case of how scientific "success" need not be based solely (or even at all) on deductive, truth-preserving inferences. Such a realization goes a long way in support of the instrumentalist conception of science.

Van Fraassen's Constructive Empiricism

Bas van Fraassen fathered the branch of instrumentalism known as *constructive empiricism*. Van Fraassen's constructive empiricism is much like the various other forms of instrumentalism in that it places emphasis on the success of a theory rather than the actual truth of it. *Empirical adequacy*, as van Fraassen calls it, is the measure of how well a given theory corresponds with observable events, and is the metric which we use to discern which theories we ought to hold. In the case that we have two equally empirically adequate theories, we should accept the theory that is more *empirically strong*, that is to say, the theory which is contains more information about the observable world. Together, the two pillars of empirical adequacy and empirical strength constitute the empirical virtues of van Fraassen's epistemology.[11]

Probably the most significant feature of constructive empiricism, however, is van Fraassen's explicit emphasis on the agnostic attitude we ought to hold toward things which we cannot directly observe. While most instrumentalist accounts hinge on the fact that there is no evidence that calls us to believe in the actual existence of theoretical entities, such as electrons, van Fraassen expressly points out that while the existence of unobservables is indeed underdetermined, we have just as little reason to believe that such things as electrons *don't* exist. By this token, van Fraassen sees it as perfectly reasonable for an instrumentalist to approach the world as if he believed a certain theory, or to subscribe to a certain "programme," without necessity of belief.[12]What van Fraassen wants is to demonstrate that "realists and anti-realists need not disagree about the pragmatic aspects of theory acceptance" even though the metaphysical underpinnings of the two camps of thought are vastly different from one another.[13]

One criticism of constructive empiricism points out that van Fraassen doesn't include the notion of simplification or unification in his list of empirical virtues. There are famous examples to which demonstrate why a taking simplicity into account might be necessary, like Nelson Goodman's famous "grue" paradox. Simply put, this paradox sets up two theories that are of equal empirical adequacy: the theory that all emeralds are green, and the theory that all emeralds are green before 2100 AD, and blue thereafter, or "grue". These theories contain the same amount of information for the same ontological entities, so we would not be able to choose between them simply on the basis of empirical strength[14]. The

[9] John Worrall, "Scientific Realism and Scientific Change," *Philosophical Quarterly* 32, no. 128 (1982): 207

[10] Alex Rosenberg, *Philosophy of Science: A Contemporary Introduction* (New York: Routledge, 2012) 210.

[11] Alan McMichael, "Van Fraassen's Instrumentalism," *British Journal for the Philosophy of Science* 36, (1985): 261.

[12] Bas C. van Fraassen, *The Scientific Image* (Oxford: Clarendon Press, 1980), 12.

[13] Bas C. van Fraassen, *The Scientific Image* (Oxford: Clarendon Press, 1980), 13.

[14] Alan McMichael, "Van Fraassen's Instrumentalism," *British Journal for the Philosophy of Science* 36, (1985): 264.

grue paradox effectively demonstrates how these two factors alone are not enough to determine which theory we ought to choose, and that simplicity and ought to be in the regimen of empirical virtues for van Fraassen.

This adjustment to constructive empiricism is quite easily rendered, however, and rather than damaging its credibility, the inclusion of simplicity and unification as theory choice criteria only serve to make constructive empiricism stronger and easier to use. Widening the applicability of constructive empiricism allows us to see with even more clarity how an instrumentalist worldview could seep through the crack of modern science to influence the thought processes of even those who claim to be staunch realists.

Clearly the mere fact that a physics professor chooses to, say, tell his students to use the small angle approximation, or the method of electric images, or some other useful fiction of science, does not mean that such a professor automatically believes that the theories being sought after by way of these instruments of knowledge are themselves fictions. But it seems reasonable to me to expect such a professor to recognize that, whether he claims to be a scientific realist or not, he already employs instrumentalist thinking in his class, and that it shouldn't be too much of a jump for him and others like him to admit that the very theories he specializes in teaching could conceivably be on the same metaphysical level as the fictions he introduces to lead students to a better understand of the theories (that is, *the theories themselves* exist solely to provide adequate explanatory power and not to reflect an objective truth about the world).

Concluding Remarks

Instrumentalism is an intriguing epistemological and metaphysical stance, not solely for its resilience in the face of the criticisms that trouble scientific realists, but also for the fact that it is extendable beyond the reaches of science itself. Instrumentalism is the way in which we interact with the world. We will believe whatever strikes the best combination of being easiest for us to understand and allowing us to make the most sense of the world, as long as the belief doesn't fail us. But while instrumentalism does extend beyond the arena of science quite nicely, it is helpful to remember that science in particular stand a lot to gain from instrumentalism, and constructive empiricism in particular. Scientists in their fields ought to educate themselves about the difficulties of a realist worldview and contemplate the utility of maintaining such a strict metaphysical stance. I think that if they did, they would find that they could easily secure the foundations of their discipline in the idea that what we want are empirically adequate theories, and how we get them is by being instrumentalists.

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