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Does the Scientific Community Misconstrue the Nature of Science?

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Abstract

The scientific community takes for granted a view of science that may be called standard empiricism. This holds that the basic intellectual aim of science is truth, nothing being presupposed about the truth, the basic method being to assess theories with respect to evidence. A basic tenet of the view is that science must not accept any thesis about the world as a part of scientific knowledge independent of evidence, let alone in violation of evidence. But physics only accepts unified theories, and persistently rejects infinitely many ad hoc rivals that fit the phenomena even better. In persistently rejecting these infinitely many empirically more successful rival theories, physics thereby makes a substantial assumption about the universe-it is such that all ad hoc theories are false-an assumption that is accepted implicitly independently of evidence, even in a sense against the evidence. That contradicts standard empiricism. The scientific community needs to adopt a new conception of science that represents the assumption of physics as a hierarchy of assumptions, thus facilitating the improvement of the assumption that is made, as science proceeds.

Keywords: Newtonian theory; Quantum theory; General relativity; Physical theory

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Introduction

The Scientific community does indeed misconstrue the nature of science. Scientists take for granted almost unthinkingly, as if it is so obvious it does not need discussion, a view of science that may be called standard empiricism. This holds that the basic intellectual aim of science is truth, nothing being presupposed about the truth, the basic method being to assess theories with respect to evidence. Considerations of simplicity, unity or explanatory power may influence acceptance of a theory as well, but not in such a way that the world itself is presumed to be simple, unified or comprehensible. A basic tenet of standard empiricism is that science must not accept any thesis about the world as a part of scientific knowledge independent of evidence, let alone in violation of evidence.

Literature Review

Scientists do not teach standard empiricism. They hardly ever advocate it, or discuss it. It is just implicit in much of what scientists do teach and publish. Nevertheless, scientists do sometimes express their conviction that a view that corresponds to standard empiricism is correct. Thus Planck once remarked "Experiments are the only means of knowledge at our disposal the rest is poetry, imagination" [1]. Or, as Poincaré put it "Experiment is the sole source of truth. It alone can teach us something new; it alone can give us certainty" [2]. Millikan expressed it like this: "the distinguishing feature of modern scientific thought lies in the fact that it begins by discarding all a priori conceptions about the nature of reality-or about the ultimate nature of the universe. and takes instead, as its starting point, well-authenticated, carefully tested experimental facts In a word, modern science is essentially empirical" [3]. Popper put it slightly more succinctly like this: "in science, only observation and experiment may decide upon the acceptance and rejection of scientific statements, including laws and theories" [4]. More recently, the President of the Royal Society in 2016 put it like this: "Science is simply the systematic accumulation of knowledge based on evidence" [5].

Despite this scientific endorsement, standard empiricism is untenable. Consider any accepted fundamental theory of physics: Newtonian theory, classical electrodynamics, quantum theory, general relativity, QED, quantum electroweak theory, the standard model. Given any such accepted theory, T, there always exist infinitely many ad hoc rival theories that fit all available evidence even better than T. These rival theories are all, quite properly, rejected. Indeed, they are not considered for a moment, not on empirical grounds, but because they are all grotesquely ad hoc. But this persistent rejection of infinitely many ad hoc rivals to the theory we accept, against the evidence, has the following dramatic consequence: it means that physics in practice just assumes, against the evidence to the contrary, explicitly or implicitly, that the universe is such that all grossly ad hoc theories are false. Or, in other words, physics in practice assumes that a thesis of uniformity is true-a thesis which asserts that true laws of nature (that are precise) are not ad hoc. That contradicts standard empiricism. For here is a thesis about the nature of the universe-a thesis of uniformity-that is accepted as a part of scientific knowledge independently of evidence, or even in a sense against the evidence. That this thesis of uniformity is indeed a part of theoretical scientific knowledge arises from the fact that infinitely many theories, that fit available evidence even better than the theory we accept, are rejected solely on the grounds that they conflict with this thesis of uniformity.

It may be objected that it is just not the case that, given any accepted physical theory, there are infinitely many ad hoc rival theories that fit all available evidence even better. In order to establish that there are always infinitely many such rival theories, let us, for simplicity, take Newton's law of gravitation as our accepted theory: $F=Gm_1 m_2/d_2$.. Let us, to begin with, consider the infinitely many ad hoc rival theories that fit all available evidence just as well as Newton's law. One such ad hoc rival is: everything occurs as Newton's law asserts up to the last moment of 2050; after that date we have the inverse cube law F=Gm1m2/d3. There are infinitely many such rival theories to Newton that, for the time being, meet with all the predictive success of Newton's theory, since there are infinitely many different times available in the future that we may take to be the date at which Newton's inverse square law abruptly becomes an inverse cube law. Even if we restrict ourselves to one specific date, the last moment of 2050 for example, there are still infinitely many rivals to Newtonian theory that fit all available data just as well, since there are infinitely many alternatives to the inverse cube law. We have $F=Gm_1m_2/d_n$, where n is any real number such that $0<n<2$ or $2<n$. And of course there are endlessly many expressions that differ from F=Gm1m2/dn, such as F=Hm1pm2p/dn, where H ≠ G, and p is any positive real number different from 1. Another possibility is F=dn/Hm1pm2p. And there are endless further possibilities. We can, for example, postulate that gravitation becomes a repulsive force after the last moment of 2050.

Infinity of rivals to Newtonian theory that fit all available data just as well can be procured by considering theories that change their form abruptly, not at some specific time, or not in some specific space-time region, but for some range of variables other than space and time, such as mass. Consider, for example, the following ad hoc rival to Newton's law: everything occurs in accordance with Newton's law except for bodies of pure gold of masses greater than 10,000 tons adrift in a near vacuum; for these bodies, $F=Gm_1m_2/d_3$.. As before, infinitely many different rivals along these lines exist, all just as successful empirically as Newton's law as far as available data are concerned.

A further infinity of such rivals to Newtonian theory can be specified by taking, not some physical system that no one has created, and no one is likely to create ever, but rather by taking an absolutely standard experiment that corroborates Newtonian theory, that has been performed countless times, and adding some bizarre detail that ensures that this particular experiment has never been performed. For example, the detail might be: 50 grams of gold dust is sprinkled around the experiment. And the rival theory asserts: everything occurs as Newton's law asserts, except for the experiment with gold dust; for this experiment, what occurs obeys the law $F=Gm_1 m_2/d_3$.

So far we have established that there are infinitely many rivals to any accepted physical theory, T that fit all available data just as well as T, but which make predictions for as-yet unobserved phenomena that differ from T. It gets worse. There are infinitely many rivals to T that fit all available data even better than T.

Given any accepted physical theory, T, almost inevitably the empirical predictions of T will fall into four categories. There will be phenomena A successfully predicted by T; there will be phenomena B that T cannot yet predict because the equations of T have not yet been solved, although in the future they may be solved, at least approximately; there will be phenomena C that ostensibly refute T, although further work may well reveal that this is not the case (invalid background assumptions have been made, experiments have not been performed correctly); finally, there will be phenomena D that lie beyond the scope of T.

Let us now assume, in order to simplify the argument as before, that T is Newton's law of gravitation. And consider that rival theory, T*, just as empirically successful as Newtonian theory (so far) that asserts: after the last moment of 2050, Newton's law of gravitation becomes $F=Gm_1m_2/d_3$. Now modify T* as follows to form T**. As far as phenomena an are concerned, T** asserts that everything occurs as T* predicts; as far as phenomena B, C and D are concerned, T** asserts that these phenomena occur in accordance with observationally and experimentally established empirical laws.

In comparison with T, T** has the following advantages. First, T** recaptures all the empirical success of T as far as phenomena A are concerned; second, T** successfully predicts phenomena in B that T does not predict; third, T** successfully predicts phenomena in C that ostensibly refute T; fourth, T** successfully predicts phenomena in D about which T is entirely silent. As far as available data are concerned, T** is better than T because T** (1) successfully predicts everything T predicts, (2) successfully predicts phenomena that T does not predict, and (3) successfully predicts phenomena that refute T. (And even if T is not ostensibly refuted, so that phenomena C do not exist, still T** would have greater predictive success than T.)

Thus, on empirical grounds, T** is a better theory than T.

In a similar way, the infinitely many rival theories, considered above, that are just as empirically successful as Newtonian theory, give rise to infinitely many theories that are even more successful empirically than Newtonian theory (Discovering how to justify the rejection of these infinitely many empirically more successful ad hoc rival theories to any accepted physical theory is of course Hume's problem of induction. The problem, as formulated here, is an intensification of Hume's version of the problem. Hume considered the possibility that the laws of nature might abruptly change, but he did not consider the infinitely many different ad hoc theories that postulate such a change. He did not consider changes in the laws of nature that arise in connection with the variation of variables other than time-such as space, mass, temperature, and so on. And he did not consider the infinitely many ad hoc theories that are even more empirically successful than the physical theory that we accept).

Thus, in general, given any accepted fundamental theory of physics, there will always be infinitely many ad hoc rival theories that fit all available evidence even better. In persistently rejecting (or just ignoring) these infinitely many ad hoc rival theories-all of which fit available evidence better than the theory we accept-we thereby accept (whether this is acknowledged or not) a thesis about the nature of the universe: it is such that all (precise) grossly ad hoc theories are false. The universe is such, in other words, that some kind of uniformity thesis is true-a thesis that holds that all ad hoc theories are false.

It is tempting to argue that the evidence has shown that this uniformity thesis is true. No ad hoc theory has been shown by evidence so far to be correct. But that conclusion only applies, at best, to the past, and to phenomena that have been observed. It does not apply to phenomena that lie in the future, or have not been observed. And as the above argument demonstrates, we have very good evidence that in the future, and for phenomena not yet observed, seriously ad hoc theories will turn out to be true. For there is this infinity of ad hoc theories, that fit all available evidence even better than the theories we accept, that predict that ad hoc events will occur in the future, or for phenomena not yet observed.

It may be objected that non-ad hoc or unified theories are inherently more verifiable, more likely to be true, than ad hoc rivals, and that is why they are preferentially accepted. But that puts the cart before the horse. What kind of theory is most likely to be true, on non-empirical grounds, depends on what kind of universe we are in. In a universe that is ad hoc in some characteristic way, theories that are ad hoc in this characteristic way would be the most likely to be true. In preferring non-ad hoc or unified theories we thereby, explicitly or implicitly, adopt the conjecture that the universe is non-ad hoc or unified.

Aim-oriented empiricism

What are the implications of accepting that the above argument is valid? It can be put like this. Standard empiricism is untenable. Persistent rejection of ad hoc theories that fit all available evidence even better than the relatively non-ad hoc theories we accept means that a big assumption about the nature of the universe is made independently of evidence (even, in a sense, against the evidence). This implicit assumption is both influential and problematic. It influences what theories physics accepts and rejects; and it influences the kind of theories that physicists seek to develop. It is problematic, first because it is not clear what the assumption asserts, it being possible to interpret "ad hoc" or "disunified" in a number of different ways, and second because it is a conjecture about the nature of the universe, very likely to be false in the specific version accepted by physics at any stage in its development [6]. It is all-important, then, that this influential, problematic conjecture be made explicit within physics so that it can be subjected to imaginative and critical scrutiny, alternatives being developed and critically assessed, in an attempt to improve the assumption that is made.

But how can physics set about improving this influential and problematic assumption in the best possible way? In order to do that, physics-and so the whole of natural science-needs to adopt and put into practice a new conception of science, a new conception of scientific method, which may be called aim-oriented empiricism: see **Figures 1**. Aim-Orien t ed Empiricism (AOE) has been expounded and defended elsewhere in some detail; here I will be brief [7] (**Figure 1**).

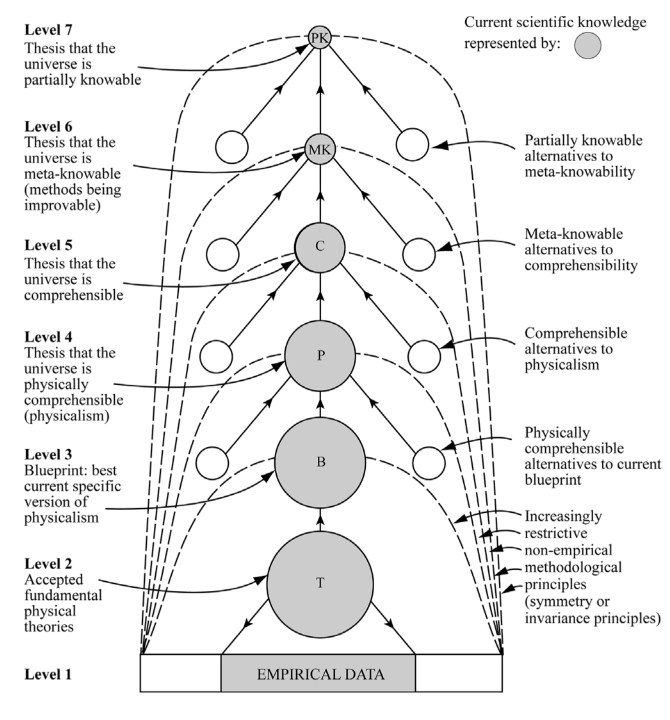

Figure 1: Aim-Oriented Empiricism (AOE).

The basic idea of AOE is to represent the problematic, implicit assumption of physics as a hierarchy of assumptions: see **Figure 1**. As we go up the hierarchy of theses, they come to assert less and less, and thus become more and more likely to be true, and also become more nearly such that their truth is required for science to be possible at all. As we descend the hierarchy of theses, they become increasingly substantial, and thus increasingly likely to be false. Criticism and attempted improvement need to be concentrated low down in the hierarchy, at levels 3 and 4 in the **Figure 1**. From level 6 to level 3, that thesis is accepted which is a particular version of the one above, and which is, as far as possible, in accordance with the one above. That level 3 thesis is chosen which accords best with the totality of accepted fundamental physical theory, at level 2.

At level 7 in the **Figure 1** we have the thesis that the universe is such that we can continue to acquire knowledge of our local circumstances sufficient to make life possible. If this thesis is false, we have had it, whatever we assume; life and science will be impossible. Even though we have no good reason to hold this level 7 thesis is true, it can never hinder the pursuit of knowledge to accept the thesis as a part of our knowledge, and may well help this pursuit. At level 6 there is the more substantial thesis that the universe is such that we can make a discovery about it which enables us to improve our methods for the improvement of knowledge. The universe is such, in other words, that we can learn how to learn. This thesis is accepted, not because we have reasons to hold it to be true, but because accepting it does more to promote, than to harm, the pursuit of knowledge. At level 5 there is the even more substantial thesis that the universe is comprehensible in some way. There is a standard kind of explanation as to why phenomena occur as the do. It might be that they occur as a result of the will of God, or to fulfil a cosmic purpose, or to be in accordance with something like a computer programme, or to accord with a unified pattern of physical law. This conjecture exemplifies the level 6 thesis since it holds out the promise that, by modifying our ideas about how the universe is comprehensible to accord with those explanatory theories that meet with the most empirical success, we will be able progressively to improve our methods for discovering and accepting new theories. The level 4 thesis of physicalism has arisen in precisely this way. It asserts that the universe is such that all phenomena occur in accordance with a unified pattern of physical law. This thesis has proved to be astonishingly fruitful empirically, in that the whole enterprise of theoretical physics accords with it. Ever since Galileo, as physics has progressed, the totality of fundamental physical theory has become both (1) increasingly unified, and (2) increasingly vast in empirical scope, in that more and more phenomena are successfully predicted with increasing accuracy. At level 3 there is our best conjecture as to what specific kind of unified pattern of physical law is inherent in all phenomena. Here, we are almost bound to get things wrong, as the historical record indicates.

Associated with each thesis, at levels 7 to 3, there are methods which require that theses and theories, lower down in the hierarchy, must be (as far as possible) compatible with the given thesis. At level 3, that thesis is to be accepted which best accords with the thesis at level 4 and, at the same time, accords best with the most empirically successful physical theories, at level 2. The hope is that, as a result of modifying the thesis at level 3 so that it accords better with the level 4 thesis, ideas for good new level 2 theories will emerge, new metaphysics leading to new physics [8]. As physics advances, and theoretical knowledge at levels 1 and 2 improve, so too conjectures at levels 3 and 4 may improve as well, this leading to an improvement in associated methods. Something like positive feedback can take place between improving knowledge and improving theses and associated methods-improving knowledge about how to improve knowledge, in other words.

Discussion

This process of positive feedback between improving knowledge, and improving methods for the improvement of knowledge, has actually gone on in science, but in a somewhat furtive, curtailed fashion, due to the general acceptance of standard empiricism and the failure of the scientific community to conceive of and adopt AOE–the hierarchical conception of scientific method depicted in the **Figure 1** [9,10]. The extraordinary success of physics is due to the somewhat constrained implementation of AOE-constrained as a result of the (mistaken) conviction of the physics community that they ought to implement standard empiricism.

What I have said so far about problematic assumptions and methods can be reformulated to be about problematic aims and methods. The basic aim of physics is not truth, as standard empiricism assumes. It is rather truth presupposed to be unified or explanatory. Precisely because this aim is so profoundly problematic-we conjecture, but do not know, that the truth is explanatory-we need to represent this problematic aim in the form of a hierarchy of aims-aims becoming increasingly unproblematic as we ascend the hierarchy, and assumptions implicit in the aims become increasingly lacking in specific content. In this way, we provide ourselves with a fixed framework of relatively unproblematic aims and associated methods (high up in the hierarchy), within which much more problematic aims and associated methods may be improved, in the light of which meet with empirical success and which do not, as we proceed with scientific research. Aims and methods evolve with evolving scientific knowledge. We improve our knowledge about how to improve knowledge, as science progresses.

A new fundamental physical theory is to be accepted if

(1) It meets with sufficient empirical success, and

(2) Its addition to the totality of accepted fundamental theories of physics sufficiently increases its accord with the level 3 thesis, or at least the level 4 theses [11-24].

Conclusion

Does it matter that the scientific community misconstrues the nature of science in the way I have indicated? It does. Natural science has made such astonishing progress during the last three centuries or so because it has put AOE into practice, even if distorted by the conviction of scientists that they ought to pursue science in accordance with standard empiricism. The progress-achieving methods of AOE have, when generalized, profoundly important implications for a variety of worthwhile human endeavours with problematic aims: for natural science itself, for the social sciences, for academic inquiry as a whole, for a variety of social, political and economic endeavours, for the future of the world. But if these implications are to be developed and exploited, it is vital, indeed necessary, that the scientific community gets into sharp focus the methodology, the conception of science that is in fact responsible for the astonishing progress of science.

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