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Popper and the Working Scientist on Logic and Method of Science

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Abstract
The maturity of science in the physics of Copernicus, Galileo, and Newton brought with it philosophical, logical and methodological questions of its development. Such questions crystallized in robust, fecund and, sometimes acerbic, debates on the philosophy, logic and method of science amongst scientists and philosophers. This is to be expected because every mature discipline lays its rational foundation and defines its boundary by its philosophy, logic and method and these questions hardly go without debates. Karl Popper's philosophical and methodological writings were mainly dedicated to articulating the rational foundation and logical-cum-methodological boundaries of science striving, in so doing, to demarcate science between non-science. Popper's tool in the effort to demarcate science and non-science is his methodological criterion of falsfication propounded in his magnum opus, Logic of Scientific Discovery 1968. The thesis of falsificationism is that a scientist should strive to falsify his theory and not to confirm it. This is contrary to the traditional inductivity or verificationist methodology of searching for confirming instances. Popper conceives the falsificationist methodology as a bulwark against dogmatism in science and authoritarianism in politics. But the scientist in his daily work employs induction and its attendant assumptions and questions the claim that a scientist should work to falsify his theory, among other heuristic components of falsificationism. Thus, a fortuitous debate ensued between Popper and his supporters on one hand, and the working scientist and his supporters, on the other hand. The result is a rich corpus on the logic and method of science. This essay x-rays such debate between Popper and the working scientist and, in so doing, contributes to the corpus.
Keywords: Working Scientist; Logic; Method; Falsificationism; Science.

1. Introduction: A Digest of Popper's Philosophy of Science.

Karl Reimund Popper is widely regarded as England's greatest philosopher of science since Bertrand Russell (Gardner, 2001) and indeed, as a philosopher of worldwide eminence. Born in Vienne in 1902 to Jewish parents, Popper had a chequerred material and intellectual career having been a primary and post-primary teacher, holder of three doctorates respectively in music, psychology and philosophy, a young Marxist frequently escaping police arrest, and a comfortable liberal ideologue naturalized in Britain and courted and knighted by the British monarchy. He died on 17th September, 1994 at the ripe age of 92.

Pooper's philosophy of science which is the subject of this discourse is one of the few contemporary philosophies that can lay claim to being a system of thought. This singular systematic quality of his philosophy lies in the feature cognizable to Popper's readers, namely, that ideas originally worked out in the natural sciences are extended and applied coherently to the political worlds. Popper claims that his preferred methodological hallmark of science, namely, falsificationism, has solved the methodological problem of induction in science; and following from there, the declared ex cathedra that falsificationism is the criterion of demarcation between science and non-science.

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Though an intricate logical and methodology principle, falsificationism is susceptible to reductionism, to wit; that every scientific theory, properly so-called, must be open to falsification (refutation) and not confirmation (proof).

The workability and acceptability of falsificationism in scientific activity is the bone of contention in this paper. Popper's construal of scientific activity is on the whole essentially artistic (Magee, 1973) in the sense of bold creative ingenuity going through the alleyways of conjectures and refutation (falsification) contrary to the working scientist's inductive investigations which climax in confirmation (proof). This difference has left a trail of tensed dialogue between Popper, the famed scientific methodologist and the working scientist on the logic and method of science, a dialogue which I believe is beneficial to the much needed scientific literacy of the generalist and sharpening of the specialist.

2. Popper and the Working Scientist on the Logic and Method of Scientific Research.

For a better appreciation of the simmering controversy between Popper and the working scientist on the logic and method of scientific research, it is necessary that we come to terms with their respective standpoints. We will start with those of the working scientist. The logical and methodological assumptions of the working scientist (otherwise known as the traditional notions of scientific method) are merely listed below, leaving aside the intricate and convoluted issue of their derivation which is bound to cast avoidable fog on the understanding of the non-specialist. The seeming epistemological disadvantage to not discussing the intricate and convoluted mechanics of their derivation will assuredly be off-set by our examination of Popper's interrogation of these assumptions shortly after listing thus;

a. That the scientist qua scientist searches disinterestedly for pure facts.

b. In the disinterested search for pure facts, the scientist employs the inductive method.

c. The scientist in his research activity first encounters facts as a matter of logical priority and, from such encounter or observation, hypotheses, theories, and laws are framed successively to account for those facts.

d. The scientist in his further professional activity seeks to confirm these theories and laws.

e .The scientist holds his theories and laws with near religious conviction and is most reluctant to let go.(Aronson,1984)

Popper questions and rejects the logical and methodological assumptions of the typical scientist and one may not treat his objections with levity. They can hardly be regarded as mere verbal quibbling of a nit-picking philosopher. Popper commands attention to be listened to for many reasons. He was a believer in, and a defender of realism- a philosophical school most supportive of science (Popper, 1972). In more practical terms, he read and taught mathematics, chemistry and physics in the secondary school (Corvi, 1997). He was therefore, very literate in science. No western philosopher, before or after him, has taught and written more profoundly and consistently than Popper on scientific method. Bertrand Russell who was going to rival him was not as profound and systematic. Popper was between 1945 and 1948 a Reader in logic of science at the University of London. At the invitation of F.A. Hayek in 1948, Popper pioneered the teaching of logic and scientific Method at the London school of Economics and political Science.

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His books, The poverty of Historicism (1957), Logic of scientific Discovery (1968) and the two volumes of the Open Society and its Enemies(1944) have been translated into ten major languages on account of the scientific rationality and attitudes they advocate and which served the western Right as a an intellectual bulwark against authoritarianism, dictatorship, superstition and violence. Of particular importance to his science pedigree was the publication of his provocative book, Quantum Physics and the Schism in Modern Physics (1982) which brought him into personal contact and further cross-pollination of ideas with famous scientists and mathematicians of the 20th century like Bertrand Russell, Boltzman, Bohr, Heisenberg, Einstein, and Mach etc.

I have at the risk of superfluity, mentioned the above exploits of Popper in the realm of logic and method of science to demonstrate his science pedigree and therefore to neutralize any suspicion and cynicism that he might be another philosophical dilettante storming into science with a typical baggage of logical analysis, argumentation and self-righteous prescriptivism.

It is against a background of buoyant science pedigree that one can appreciate the singular intelligibility and plausibility of Popper's engaging dialogue with the working scientist. Popper rejects the above traditional methodological assumptions of science because they constitute inextricable accompaniment of the inductive method which Popper sets out to dethrone as the methodological cannon in science. In its place, Popper advocoates falsificationsim.

Of course, Popper has good reasons for advocating falsificationism in place of inductivism. What has come to be known in the philosophical world as "the Humean Problem" or "problem of induction" forms the basis of Popper's search for a methodological shift in scientific activity. The Humean problem or problem of induction lies inextricably in the inductive process itself. In the inductive construal, scientific investigation is claimed to start with observations and moves on from them to generalizations (theories and laws) and predictions.

The Scottish philosopher, David Hume (1711-1776) raised critical questions about the logical validity of deriving scientific laws or theories from observational data. Hume pointed out that no number of singular observation statements, however large, could logically entail an unrestricted, general statement such as is the nature of scientific laws and theories (Stumpf, 1977). Hume concluded therefore that our inference of scientific theories and laws from few observed instances is a matter of expectation based on habitual experience, a matter of psychology and not a matter of logic (Stumpf, 1977).

Equally bereft of logical foundation, according to Hume, is the attempt of justify induction by the principle of uniformity of nature: the belief that everything that has happened or will happen is an instance of some general law to which there are no exceptions. Under this principle, the business of science is held to be the discovery of uniformities such as the laws of motion and the law of gravitation to which so far as our experience extends there are no exceptions (Russell,1912). But again a logical question pops up. Have we any reason, assuming that they have always held in the past, to suppose that they will hold in the future? We must remind ourselves in this connection that Newton's laws of motion and gravitation were experimentally confirmed and held to be true for close to 400 years. Yet in the early 20th Century, quantum mechanics and Einstein's relativity theory furnished different laws of energy radiation and gravitation. Of particular interest

is Einstein's general theory of relativity which predicted significant deviation from Newton's law of gravitation. One of these deviations was confirmed in the eclipse experiment of 1919.

Reacting to this logical problem of induction, the world famous British mathematician and philosopher, Bertrand Russell, held that while induction cannot be jettisoned in scientific investigation, we will give up the quest for certainty and make do with probability (Russell, 1956). He further reasoned that: "*What* these arguments prove and I do not think the proof can be controverted- is that induction is an independent, logical principle incapable of being inferred either from experience or from other logical principles and that without this principle science is impossible"*(*Russell,1956*)*

Popper would neither agree with Russell and other scientists that induction cannot be jettisoned nor that it is an independent logical principle. Instead, he formulates an alternative method, falsificationism, which he claims has solved the above-discussed problem of induction. Popper accepts Humean skepticism about induction taking on board the consequence that this means that we can never know whether any universal theory is true. This skepticism led Popper to formulate the falsificationist method which gives an account of scientific rationality on the basis of negative activity of attempting to disprove theories. The empirical disproof of a theory, Popper rightly holds, is conclusive while any amount of evidence in favor of a theory is inconclusive.

A practical example (Magee, 1973) will illustrate Popper's refutability or falsifiability criterion as the demarcation between science and non-science. One is taught at school that it is a scientific law that water boils at 100^{o} centigrade. No number of confirming instances will prove this, but by the refutability or falsifiability criterion one can nevertheless test it by searching for circumstances in which it does not hold. This alone challenges us to think of things which, so far as we know, no one else has hit on. If we are imaginative, we will soon discover that water does not boil at 100^{o} centigrade in closed vessels. So, what we thought was a scientific law turns out not to be one. At this point, we could salvage the original statement "water boils at 100^{o} centigrade" by narrowing its empirical content to "water boils at 100^{o} in open vessels". And we could then look systematically for a refutation of our second statement, and so on.

Yet another illustration of Popper's method: the Statement "All Swans are white" (a universal statement with the same logical character as scientific theories and laws) can never be proved conclusively. But it can be disproved or refuted conclusively by a single instance of a swan that is not white, say a black swan. This tentatively warrants the statement "All swans are not white" which is both logically and empirically more reliable than the statement "All swans are white".

The method of conjectures and refutations implicit in the above illustrations constitutes Popper's original, howbeit, controversial contribution to the questions of logic and method in contemporary science and this he aptly renders in the following quote:

> *"Knowledge can grow, and science can progress- just because we can learn from our mistakes. The way in which knowledge progresses, and especially our scientific knowledge, is by unjustified (and unjustifiable) anticipations, by guesses, by tentative solutions to our problems, by attempted refutations, which include severe critical tests. They may survive these tests; but they can never be positively justified:*

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> *they can neither be established as certainly true nor even as "probability" (in the sense of probability calculus)" (*Popper, 1963*).*

The above quote, in a nutshell, is Popper's view of the way scientific knowledge advances. It is against this background that it will become clear why it is inherent in Popperian logic and method of science that what we call our knowledge is by its nature provisional, and permanently so. At no stage are we able to prove that what we now "know" is true and it may turn out to be false. This methodology lead's beneficially to critical attitude as the hallmark of scientific rationality. But unfortunately, the inductive methodology which the working scientist so much relies on, by its own logic, craves after verification and proof and this is one of the reasons why Popper vehemently calls for the abandonment of inductivism.

The consequence of this controversy on method between the working scientist and Popper is ironic: The working scientist in his desire of upholding scientific rationality as the standard of dependable knowledge accepts the *critical attitude* and its implicit fallibilism which are the direct logical products of falsificationism but opposes falsificationism itself as a method. In a figurative sense, the working scientist opposes a tool but relishes its products!

It would seem therefore that the working scientist has not yet shaken off the psychological relics of old inductivism which incorrigibly holds that science eventually leads to the certainty of a definitive explanation and it's implication that it is grave scientific misdemeanor to have published some hypothesis or theory or law that got falsified. This die-hard inductivist psychology accounts for why scientists have often been loath to admit the refutation of their hypotheses or theories and their lives may be spent defending the no longer defensible. This psychology formed the theme of Thomas Kuhn's classic, *The Structure of Scientific Revolution* (1978). Even the renowned theoretical physicist, Einstein fell hostage to this psychology when as a scientific idealist and determinist he opposed Popper's realism and Max Planck's quantum paradigm, rejecting the later with the emphatic declaration "I cannot believe that God plays a dice" with the cosmos (Barnet, 1957) But from facts of history of science, Popper's methodology of falsification is the proper logical and methodological characterization of scientific activity. This is because falsification in whole or in part is the anticipated fate of all scientific hypotheses, theories and laws.

Logically inherent in Popper's rejection of inductivism and verificationism or proof is his rejection of the so-called traditional scientific assumptions that the scientist incorrigibly searches for facts and that facts can be dichotomized from theory. The thread of Popper's strained dialogue with the working scientist also extends to these issues.

The working scientist's inductivist methodology claims that the scientist proceeds first by collecting observations or data and then inferring laws and predictions from this data by induction. Popper contends that the logic of research as revealed by the history of major scientific discoveries say much more. Such history, Popper maintains, shows that the scientist cannot simply observe without a theoretical background and therefore the so-called inductivity dichotomy between "pure facts" and pure observation collapses. Popper illustrates this point thus:

> *"The belief that we can start with pure observation alone, without anything in the nature of a theory is absurd… Twenty five years ago I tried to bring home the same*

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point to a group of physics students in Vienna by beginning a lecture with the following instructions: "Take pencil and paper; carefully observe and write down what you have observed" they asked, of course, what I wanted them to observe. Clearly the instruction, "observe" is absurd.. Observation is always selective. It needs a chosen object, a definite task, an interest, a point of view, a problem" (Popper, 1963)

What informs Popper's opposition to the inductivist concept of "pure fact" or "pure observation" is his wider conception of the logic of scientific discovery which accommodates the role of creative intuition or imagination in scientific investigation (Magee, 1973). This role is palpable in Popper's formulation of bold conjectures and refutations, a kind of bold creative inventiveness in contradistinction to the inductivist, classroom science of mechanical observation.

Here again, facts of history of science are on the side of Popper. Such history reveals that the so-called "pure facts" do not lie undisguised. They require some creative inventiveness and imagination and intuition to be discovered and formulated into their popular intelligible forms. When Isaac Newton sat under the apple tree and saw an apple fall, there was no "pure fact" of gravity that presented itself to him. When Archimedes immersed himself in the bath bowl, there was no "pure facts" of floatation mechanics that presented themselves to him.

What then must be responsible for the recalcitrant assertion of the working scientist that he objectively searches for pure facts and that there is a dichotomy between facts and theories? An absolutist and presumptive ideology is responsible; an ideology that imposes and presents scientific rationality as the paradigm epistemology, as the standard of reliable knowledge. This is an ideology which, out of a frenzied scare of anything metaphysical, seeks to place the lid on anything that does not come within the ken of the five senses.

Ironically, Popper, through his methodological writings on science contributed to shoring up this absolutist ideology of science as the paradigm knowledge. He declares magisterially in his objective knowledge (1972) that epistemology is exclusively the theory of scientific knowledge. (Popper, 1972) However, Popper exonerates himself from this absolutism in his later works where he canvassed the view that a theory may not be scientific and still be useful. He cited the doctrine of atomism as an example (Popper, 1968). This later view accounted for his insistence on the cleavage between his "science and non-science demarcation program" and the logical positivists' "program of demarcation between the meaningful (science) and the meaningless (non-science)" (Popper, 1968).

Popper's strained logical and methodological dialogue with the working scientist gets tougher on the following questions:-

1. Does the scientist abandon his theory as soon as he comes upon a counter or falsifying instance?

2. Does the scientist work to confirm his theory or to falsify it?

Criticisms have been mounted by working scientists against instant abandonment of falsified theories as they claim it is implied by Popper's falsificationist methodology. It is contended by working scientists that they do not "abandon" a theory on coming upon a falsifying instance; that experimental efforts are made to save the theory and that it is only after prolonged efforts at saving the theory and it still

fails that the theory is grudgingly dropped. Popper is accused by scientists of not capturing their professional procedure in his methodology. But Popper shrugs it off. He maintains that he did not mean naïve falsificationsim such as the working scientist's understanding of his methodology suggests. He argues that he should rather be seen as a methodological or critical falsificationist, that he should be seen as saying that at the end of the saving efforts, at the end of the day, the scientist gives up the falsified theory.

This simmering logical and methodological dispute incurred the intervention of Popper's able pupil and later a colleague, Prof. Imre Lakatos, who set out on a buoyant revisionary interpretation and emendation of Popper's methodology in his (Lakatos's) Methodology of Scientific Research Programme 1978.

The second question of whether the scientist works to confirm or refute his theory did not fare better in the dialogue. Scientists argue that they do not in their work seek the refutation of their theory or law. Instead, they seek confirming instances. For example, in the theory of expanding universe, the astronomers are not trying to falsify it, they are not trying to see the universe is not expanding, but are seeking for facts that it does expand. Again, in the boiling point of water, experimenters are not looking for falsifying instances, they are not looking for water that will not boil at 100^{o} centigrade, but are trying to confirm that water boils at 100^{o} C. Popper dismisses these remonstrations as ingrained psychology of research and maintains that logically and methodologically, what differentiates scientific theory or law from their metaphysical counterparts is that the former must face refutation. What is irrefutable, unfalsifiable and, therefore, dogmatic is metaphysical theories or laws such as the law that "everything that has a beginning must have an end", "everything has a cause" or the theological theory that "the cosmos was created by an intelligent Being" etc (Popper, 1972).

3. Conclusion

The dialogue between Popper and the working scientist is not a harmonious one. Yet science continues to make progress as Popper envisioned in his theory of verisimilitude. Science continues to churn out new explanatory theories and laws which spur new technological productions. Who then is right? Popper or the working scientist? An answer does not require one coming down on one side of the methodological debate. It would seem, on one hand, that much of what is involved in scientific activity has not been captured in human words as methodological principles; on the other hand, the working scientist has not yet gained full knowledge and mastery of the manifold ramifications of matter which he tinkers with. It is neither a matter of logic nor psychology of research, but a matter of the elusiveness of profound scientific truths. We need fecund and mind to unfold the mysterious wrappings in which nature is presented to us.

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