Scientific Thought and Common Sense

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> ***I am sitting with a philosopher in the garden; he says again and again "I know that that's a tree", pointing to a tree that is near us. Someone else arrives and hears this, and I tell him: "this fellow isn't insane. We are only doing philosophy."***
> **Ludwig Wittgenstein, *On certainty*, n. 467.**

Abstract. The interplay between realism and instrumentalism in science is discussed by taking into account how they are providentially mixed in the practical work of the scientist. The basic realistic stands (realism of theories, realism of theoretical entities) are analysed with particular attention given to the latter one. The fact that we measure a property of a theoretical entity (a physical quantity in Physics) does not allows us to say that the theoretical entity in question exists. Neither does the fact that we "manipulate" the theoretical entities. Ontological assertions about the existence of theoretical entities cannot be logically deduced from the acquired knowledge nor can they be empirically verified. Ontological images of the world built by scientists should be compatible with the acquired knowledge and are, at best, only plausible. The reliability of their persistent ontological components increases with time. The basic realistic assumption shared by science and common sense cannot obscure the fact that the image of the world of common sense is far from satisfying the average rationality standards of the

scientific enterprise. This situation should be of great concern to the scientific community, since in the "world" of common sense regressive cultural stands and behaviours can give rise to social contexts hostile to rational attitudes and to the various manifestations of intellectual life (scientific, artistic and religious). The cultural and civil responsibilities of scientists are not primarily related with the technical and military applications of science, but linked to the contribution that science can give in the elaboration of a common sense rationally oriented.

Realism and instrumentalism. Albert Einstein claimed that the scientist might appear to the systematic epistemologist as an unscrupulous opportunist: he appears as realist, idealist, positivist or even as platonist or pythagorean (Schilpp, 1949).

Einstein's defence of the scientist's "opportunist" behaviour helps us in understanding the interplay between two opposite philosophical and epistemological stands: realism ***and*** instrumentalism. In scientific ***practice***, realism and instrumentalism never occur in a pure form: the scientist is always realist ***and*** instrumentalist**. *The scientist at work*** - as a common man in his daily life - believes in the existence of an external world, observer's independent; at the same time, the need of predictability makes him an instrumentalist. The blend of realism and instrumentalism is largely present in the historical development of science. Planck has stressed that the realistic component tends to prevail when the physical image of the world is rather stable; the instrumentalist one, instead, in times of innovations and changes.

Instrumentalism. According to the instrumentalist stand, scientific theories are merely devices for making predictions with no ontological commitments. As Hertz put it: "The most direct, and in a sense the most important problem which our conscious knowledge of nature should enable us to solve, is the anticipation of future events, so that we may arrange our present affairs in accordance with such anticipation".

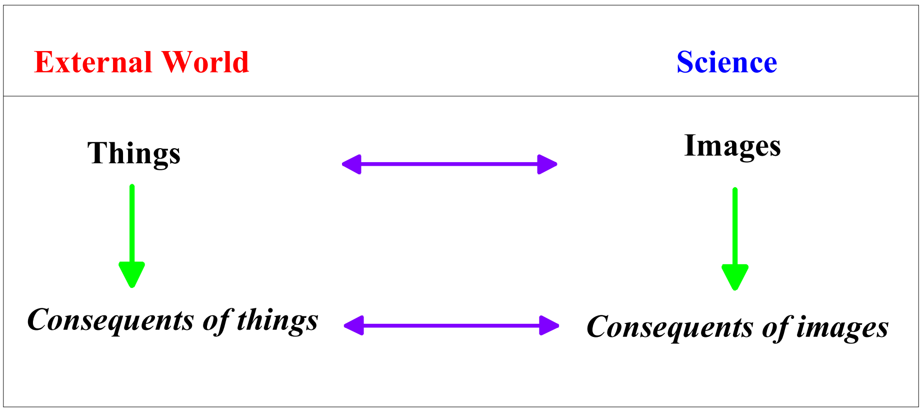

Table 1. Schematic diagram of the relation external World-Science, according to Hertz.

In order to get this aim

"We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured [. . .] The images which we here speak of are our conceptions of things. With the things themselves they are in conformity in ***one*** important respect, namely, in satisfying the above - mentioned requirement."

Scientific realism. Scientific realism is based on three fundamental postulates:

A1 A world exists, independent from the observer, whom the observer belongs to

In the historical development of science we can find positions that have denied or considered worthless the realistic stand. Nevertheless, the realistic stand has constituted the underlying layer of the scientific enterprise. Two other presuppositions have grown on this basic layer:

A2 Every event has a cause (causality principle)

A3 World's behaviour is constant in time (phenomena are reproducible)

We can assert that: A1 is a ruling principle for common sense and science; a stand oriented by A2 has strengthened the predictive and explicative capacities of science; A3 has been, up to now, reasonably corroborated.

These three presuppositions support also the rational components of common sense.

The fundamental problem of scientific realism may be stated as follows: which are the relations among world, phenomena, experiments, theories and images of the world?

In dealing with this problem, we shall focus on the case of Physics: the considerations developed below can, probably, be extended to other experimental disciplines with suitable modifications.

Realism of theories. The realist stand is usually analysed in terms of realism of theories and of realism of theoretical entities. The realism of theories holds that a corroborated theory describes exactly how things go into the world. It has been basically challenged by the following objection: in order to hold that a theory describes how exactly things are, we must know - independently from the theory - how exactly things are. The realism of theories implies also the real existence of all the theoretical entities used by a theory and the attribution of general features of theories to the external world.

For instance: from the fact that quantum mechanics is a probabilistic theory it is inferred that the world is indeterministic. The validity of this conclusion is based on the untenable assumption that a corroborated theory describes exactly how things are.

The attribution of general features of theories to the external world constitutes an instance of improper use of ontological statements. Another example is given by the embodiment of ontological statements into the set of postulates of a theory. This use is improper because particular ontological statements should be made only a posteriori: their embodiment into the postulates of a theory transform them into a priori statements.

Realism of theoretical entities. The realism of theoretical entities holds that, at least, some of the theoretical entities used by a theory exist. By referring to the case of Physics, we shall try to see what experiments tell us about the existence of theoretical entities.

Theoretical entities and physical quantities. Theoretical descriptions in Physics use two types of concepts: theoretical entities (particle, wave, field, electron…) and physical quantities. Physical quantities describe properties of theoretical entities (for instance, mass, charge, spin and magnetic moment of an electron) or relations between theoretical entities (the velocity of an electron with respect to a reference frame).

The measurement. The basic feature of a physical quantity is that it can be measured. In a typical process of measurement, a physical quantity ***G*** associated with a theoretical entity ***E*** is measured by an apparatus ***A***. Within the theory we are using, the outcome of the measurement depends on the interaction between the theoretical entity ***E*** and the apparatus ***A***.

The *quid*. If the measurement is significant, its outcome cannot be entirely attributed to the apparatus: therefore, we must say that it reflects a property ***P*** of a ***quid Q(E)*** which, in the world, corresponds to the theoretical entity ***E***. ***The quid Q(E) may be something very different from the theoretical entity E as described by the theory***. The fact that we measure the wavelength of an electromagnetic wave does not allow us to say that electromagnetic waves***, such as described by the theory***, exist in the world.[1] Again: the fact that we measure the

[1] The statement that electromagnetic waves, such as described by the theory, exist, is incompatible with Maxwell's theory. Let us consider the classical interference experiment with two slits. If we assume that electromagnetic waves exist, we must say that a wave leaves from slit ***A*** and another wave leaves from slit ***B***. Both reach every point of the screen ***S*** on which we observe the interference pattern. Let us now consider a point ***P*** on the screen ***S*** belonging to a dark fringe. We must say that a fraction of the energy carried independently by both waves reaches point ***P***. However, in ***P*** there is no energy: the lacking energy must have gone - through a

charge and the mass of the holes in a semiconductor, does not allows us to say that the holes exist.[2] We "inject" them through a junction, but, very likely, they do not exist.

The image of the world. The assertion that a theoretical entity exists implies an ontological ***assumption***. Ontological assumptions are necessary if we want to build an image of the world. An image of the world cannot be deduced logically from the acquired knowledge, but it must be consistent with it. If an image of the world considers a theoretical entity as existent, we can denote this theoretical entity with the term **"*object*",** because it does not substantially differ from a typical object of our daily life.

The existence of common things that are directly perceived by our senses seems (almost) non-problematic.

The existence of, say, electrons might appear as much more problematic because they are not directly perceived by our senses. However: the instruments that measure properties of electrons do the same thing as, for instance, our eyes that measure the properties of the light emitted by the ***quid*** that they "see".

When physicists manipulate electrons or protons with accelerating machines they, very likely, have no doubt about their real existence and, consequently, they adopt precautions for avoiding biological damages. The physicists' behaviour is a rational one; however, it cannot be taken as a proof for the existence of electrons and protons, ***exactly as described by the theory***.

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process not described by the theory - to some point of a white fringe (which?), as required by the theory. The assumption that electromagnetic waves exist introduces a causal anomaly in the description of the theory: therefore, it is incompatible with the theory itself.

[2] In this case, the theory itself explains that the theoretical entity "hole" describes the properties of many electrons in the valence band of a semiconductor, in presence of a much small number of unoccupied states. However, when the band theory of solids was still unknown, some physicists believed in the existence of positive free carries in solids because they were able to measure their positive charge. See, for a brief discussion of this topic: G. Giuliani, "What physicists are talking about?", in A. Balzarotti, A. Frova, U.M. Grassano, (eds.), "Solid State Physics", *Il Nuovo Cimento* 20D, (1998), 1183-1186.

The image of the world - as the acquired knowledge on which it is based - is the product of a historical process. It has two main features: a) it changes with time; b) the reliability and stability of its unchanged components increase with time. This point is particularly important because it suggests that ontological assumptions can reach a stability greater than that of the acquired knowledge on which they are based. For instance, if we assume ***now*** that the theoretical entity electron exists, we can assert that this ontological assumption has lasted and will last more than the acquired knowledge on which it was and will be based. The theories describing the electron have changed in the past and may change again in the future; but we are confident that the electron will be a component of the images of the world to come.

The acquired knowledge makes assertions about the world; however, the acquired knowledge can only speak of ***quid*** and of properties of ***quid***: in order to speak of the existence of theoretical entities we must build an image of the world based on ontological ***assumptions***.

The image of the world: pro and cons. All the activities of human beings are oriented by an image of the world. The image of the world of a scientist at work helps or guides him in devising new experiments or imagining new theories. However, often the scientist forgets that every image of the world - even the one that may appear compatible with the acquired knowledge - contains ontological ***assumptions*** and, consequently, is, at best, only plausible. As a consequence, the scientist may be induced to contrast new ideas or theories that appear or are incompatible with his cherished image of the world. The history of Physics presents many cases of this kind. It is well known, for example, that relativity principles and their consequences have been contrasted on the basis of a Newtonian image of the world; that the proposal of the light quantum provoked a hostile and tenacious reaction based on an image of the world characterised by the undulatory description; that Einstein's fight against the new-born quantum mechanics, prompted by his realistic stand, was certainly not in accordance with his call for an "opportunist behaviour" by the scientist.

Scientific community and common sense. The complexity of the category of "common sense" asks for a very cautious approach to this relationship. First of all, it is worth emphasising that the "and" in the section title is justified by the basic realistic assumptions shared by common sense and science (the existence and the regular behaviour of an independent external world and the causality principle) and by the fact that both scientists and common men use in their activities an "image of the world".

The image of the world of common sense is the product of natural selection and of historical processes: it has secured the success of human species.

Obviously, many beliefs and behaviours induced by common sense ***are*** very far from conforming to the ***average*** rationality standards of the scientific enterprise. The evaluation of the rationality of common sense with respect to that of the scientific enterprise does not imply that the rationality of the latter is an absolute one. Human rationality, both in common sense and science, is a bounded one: however, scientific rationality has historically proved to be a model particularly powerful, reliable and progressive.

On the other hand, the basic features of common sense should constitute a necessary component of the conceptual pattern of the scientist's commitment against the most paradoxical implications of sceptical and anti-realistic positions.

The cultural commitment of the scientific community. Traditionally, common sense has grown and consolidated by answering to challenges that were spatially and temporally limited. Nowadays, economic and technological determinations are global and their lasting effects might strongly reduce the possible choices of the generations to come. This new situation challenges both common sense and scientific community. The cultural and ethic responsibilities of the scientific community should primarily be concerned with the tasks of education and diffusion of scientific knowledge. Problem solving strategies based on scientific thought are, more and more, vital to human species.

On the other hand, common sense accumulates regressive cultural stands and irrational fears induced by pseudo-scientific popularisations. Scientific illiteracy can give rise to social contexts hostile to rational attitudes and to the various manifestations of intellectual and civil life.

A common sense dominated by irrational components exposes also the scientific community to the risks of contamination and depletion of its best heritage.

Men of science should care about it because “we belong to a community which is bound together by science and education”. (Wittgenstein, 1969, n. 298).

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