The Relation between the observed and the observer in Scientific Cognition

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1. THE ROLE OF EXPERIMENT IN THE METHODOLOGY OF SCIENCE

Galileo established science (throughout this text I shall consider Physics as the paradigm of science) as an independent and autonomous cognitive process. He did this with the introduction of the concept of experiment into the methodology of science. Before Galileo science was just a part of philosophy in general where the methodology is observation followed by intellectual speculation or, sometimes, purely intellectual speculation. Galileo distinguished science from philosophy, once and for all, by establishing experimentation as an integral part of scientific investigation of the nature of reality. Note that the scientific query, that is, asking questions about the nature of reality and, the subsequent human endeavour to discover the causal relationships existing among the natural phenomena is as old as the history of human consciousness. But this was just a part of the basic inquisitiveness of human beings and the approach towards such questions was not fundamentally different from the approach of philosophy. It is Galileo who gave the concrete definition of the scientific methodology. *Science connecting theory and experiment really began with the work of Galileo. (P-52, The Evolution of Physics, Albert Einstein & Leopold Infeld.)* In this sense, modern science dawned with Galileo.

Now the cognitive process of science (as established by Galileo) is speculation—(laid down in the form of a hypothesis)—experimentation-verification. In this context it should be mentioned that though verification is the way to establish a scientific theory, the essence of a theory which is scientific lies in it's fallibility rather than it's verifiability. This was rightly pointed out by Sir Karl Popper, the famous philosopher of science of our age. Experimentation, thus, forms the very basis of scientific cognition. Therefore, it is worthwhile to ponder over the concept of an experiment.

What really is an experiment, after all? Let us consider a simple experiment carried out by Newton, actually an experiment conceived and carried out by Galileo himself but later by Newton in an improved way. The objective of the experiment was to see whether all bodies fall from a particular height with the same velocity or not. The notion that was prevalent at the time of Galileo was different bodies fall with different velocities. Well, Newton inserted a penny and a feather inside a long glass cylinder. He pumped out the air during the fall. He kept the glass cylinder vertically upright so that both the penny and the feather was at the bottom and then abruptly turned it upside down. It was observed that the feather which is far lighter than the penny, and the penny, both reaches the bottom of the glass cylinder simultaneously thus proving that the common notion does not tally with reality, at least it does not tally with the outcome of the experiment. In the original version of the experiment, as we all know, Galileo dropped different objects from the top of the leaned tower of Pisa. The historical truth of this story, however, is yet to be established beyond doubt. But that Galileo carried out similar experiments (for example rolling different spherical objects along an inclined plane and noting the time of their fall) is known beyond doubt.

What is significant about the whole story is the fact that the notion that was disproved by this experiment was also based on experience. You simply drop a coin and a feather together from a certain height and watch the result. You will see that the coin reaches the ground earlier than the feather. If there is a wind strong enough to divert the feather to some extent from the vertical path but not too strong so that the feather is blown out of sight, the delay of the feather will be

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more evident. It is this simple day-to-day experience and observation that led people believe in the gross generalization that heavier objects fall more quickly than the lighter objects.

Now, what is the essence of the thing done by Newton through this experiment? To verify the truth of a certain preconceived idea about a natural phenomenon, Newton repeated the occurrence of the concerned phenomenon deliberately in a contrived and artificial way, a way in which the phenomenon never actually occurs in nature, and demonstrated that the result contradicts the preconceived idea held by people till then. Using the terminology of science we can say that he proved the hypothesis to be false. Please note that the hypothesis was not the product of pure imagination. It also was based on experience and observation, our day-to-day experience of the world. But, just because it does not tally with the experience and observation of a single case (and that also is the case where the phenomenon was repeated in an artificial environment !) we are discarding it and concluding the contrary statement that from a particular height all objects fall with the same velocity. Why are we giving more prestige to one particular observation, in this case the observation of the results of the experiment, than the others? The answer to this question is rather involved and is not directly related to the present discussion. I shall leave the issue for the reader to ponder over. Right now we shall try to grasp the meaning of the word 'experiment' which happens to be a keyword in scientific cognition.

Let us once more watch the activities of Newton while he is experimenting with the penny and feather. In the world around us we never see things falling through vacuum. Still, to investigate the way things fall he tried to make thing fall through vacuum. Why ? Because he felt that the existence of air inside the cylinder is a disturbance, as far as the movement of a body towards earth is concerned. Why should we consider the existence of air to be a disturbance ? Because we implicitly assume that the phenomenon of falling has nothing to do with air, they are totally unrelated. In this way science tacitly brakes reality into myriads of compartments, presumably unrelated, and then strives to know them separately. Experimentation is a way to concentrate on the particular phenomenon we are concerned about. The irony is, the objective of science is to find a pattern i.e. a causal relationship between diverse and apparently unrelated phenomena. This purpose is served as the scientist tries to find more and more generalized theories that embraces wider spheres of diverse and apparently unrelated phenomena (unrelated to the immediate sense data). For example, the phenomenon of high tide and low tide of the oceans and the fall of a mango from a tree are united by virtue of the theory of gravitation though, as far as our immediate sensuous experience of these phenomena are concerned, they are unrelated. Of course he, the scientist, takes into account the knowledge already accumulated by the human race through ages.

Thus, the essence of experimentation is to prepare an artificial environment, commonly known as the experimental set up, where for the sake of concentrating on a single phenomenon the occurrence of that phenomenon can be repeated in a manner detached from other phenomena. The main concern is to facilitate a particular aspect of reality to be highlighted. Based on the observation of the outcomes of the experiments the scientist draws conclusions related to the phenomenon which either validates or invalidates some hypothesis. So long as a theory is consistent with the results and observations of experiments it is considered to be valid. Whenever people begin to find phenomena which does not fit into the pattern already laid down by some previous theory, the theory is considered to be inadequate and scientists search for a new theory. A new theory is considered to be valid and in some sense closer to truth if it's predictions tally with the observations and results explained by the previous theory plus the new observation which the old theory could not explain. The fate of the new theory is, perhaps, no better. This will also be obsoleted by some other theory which might be able to unite a larger number of phenomena through it's explanations. In this sense any scientific theory is fallible, by virtue of it's being scientific. Science believes that it gets more and more close to truth in this way.

2. THE ACT OF OBSERVATION, THE OBSERVED AND THE OBSERVER

Science, as we all know, is concerned with the objective reality, a reality which is impersonal. It is termed as "objective" to differentiate it from the "subject" i.e. the agent that experience and perceives it, and also, to stress upon the point that whether there exists a subject by whom it is being perceived or not, it exists anyway. Thus, the properties of light can be studied through scientific methodology, but not the aesthetic sense of human beings. After all, light exists by itself (whether we are being enlightened by it or not) but a sense of beauty presupposes the existence of the connoisseur. (But that does not imply that beauty is something purely imaginary. In fact, the beauty of a painting by Jamini Roy is no less objective than the painting itself, but the objectivity of beauty is different from the objectivity of a screw driver.) Again, we are talking common sense. According to Bishop George Berkeley, that eloquent idealist, the essence of existence is it's being perceived (or in the very act of perceiving, *esse est aut percipere aut percipi)* so that any assertion about existence presupposes the existence of some subject in the act of perceiving it, explicitly or implicitly. Science, however, is built on the faith that things exists by themselves.

Any experient, in fact any act of experience, observation, perceiving is necessarily associated with two agents, namely the reality that is being investigated, experienced, observed or perceived and, the agent who is experimenting, experiencing, observing or perceiving. We shall use the words "observed" and "observer" to talk about these two agents respectively. Also, we shall use the word "observation" to denote the interaction between the observed and the observer in general.

3. THE OBSERVED-OBSERVER RELATIONSHIP IN CLASSICAL PHYSICS

The world view of the classical physics is primarily based on Newtonian mechanics and Maxwell's Electro-magnetic theory. It reigned the world of Physics till the middle of the nineteenth century. After that it's inadequacy was revealed as the physicists came across more and more phenomena those could not be explained by the concepts of classical physics. I am not going into the details of these events because, firstly, that will not illuminate the issue we are concerned about in this text and, secondly, too much technical physics is involved there. However, the crisis was prevalent until in 1900 Max Plank proposed a theory which explains the observations nicely but simply absurd if you try to visualize it. He proposed that light waves travel in small packets and named those small packets of light (containing definite amounts of energies, depending upon the frequency of the light) as Quanta. That was the end of the classical Physics and beginning of the Quantum Physics. The next revolutionary idea came from Einstein. In 1905 he put forward the famous Special Theory of Relativity where he discarded the idea of absolute space and absolute time, so dear to the classical physics. The conclusions were still more tantalizing and so famous that it is hardly necessary to repeat them once more. A change in the flow of time with velocity and equivalence of energy and mass are the two results most difficult to digest. Still, the range of phenomena that comes under the jurisdiction of the classical physics is awe inspiring. The final blow to the classical world view came from Warner Heisenburg in 1927 as he proposed the famous Uncertainty principle. We shall discuss the impact of this Uncertainty principle on the philosophy of science.

In classical physics it is taken for granted that while an experiment is being carried out the reality that is being investigated is not affected or altered by the very act of experimenting. Unless we assume this, our whole effort to reach truth is hopeless because, if the experiment itself alters the reality it is experimenting then what we obtain as a result of the experiment is necessarily a distorted version of reality and therefore unreliable. Hence, in classical physics it is assumed that (a) the observed phenomenon is independent of the act of observation as well as the consciousness that make the observation, (b) the act of observation does not disturb the observed reality significantly so that the observation may be taken to be authentic. The word "significant" is important. It is obvious that since an observation is nothing but an interaction between the observed and the observer it is bound to render the observed reality a little bit altered. But the optimism of the classical physics lies in the assumption that it is just a matter of delicacy of the act of observation. In principle, you can make more and more delicate instruments to assist your observation so that the effect of the act of observation on the observed phenomenon can be minimized without limit. Moreover, the principle of causality guarantees us to predict the future with the help of the natural laws. Nature, as such, does not prohibit you to know her.

4. THE OBSERVED-OBSERVER RELATIONSHIP IN QUANTUM MECHANICS

As stated earlier, in 1927, Warner Heisenburg shattered this faith of classical physics in the frankness of Nature to reveal herself with his famous Uncertainty Principle. The uncertainty principle asserts that you cannot measure the position as well as the momentum of a particle simultaneously with arbitrary accuracy. The more accurately you get the position of the particle the less accurate is it's momentum and vice-versa. And this is not just our fault. The very act of an observation, in this case the measurement of the position and the momentum, is such that this uncertainty creeps-in in the information thus obtained. There is a well defined quantitative relation between the uncertainty in the information about the position and that of the momentum but that is not important in the present discussion. The point is, while a phenomenon is being observed the act of observation has to be taken into consideration and reality, (even if it is objective) as it appears to us i.e. the subject, should be considered to be the outcome of the interaction between the observed and the observer. For our macroscopic world of experience, however, the classical point of view is quite adequate. But when you are concerned with the micro world of quantum mechanics, a world consisting of entities like electron, proton, photon and other subatomic "particles", you have to get rid of the vision built on common sense. I have written the word particles within quotes because whenever we say "particle" our consciousness tend to picture it as something akin to a billiard ball—solid, round, tangible, colorful and so on. Since we sense the world around us with the help of the five senses, it is impossible for us to imagine (here, by imagination I mean a mental experience of some "object") something beyond the realm of the five senses. An electron is a particle as well as a wave or perhaps neither. It is meaningless to ask what an electron "really" is. Now, instead of talking in technical terms, I would like to present the problematic of quantum mechanics in the form of a simile. Imagine yourself in a completely dark room. Inside the room there are some objects made up of glass lying here and there. Your eyes are covered so that it is impossible for you to see anything. The glass objects are so fragile that as soon as you touch them they break. In this situation you are trying to know the actual shape of the objects. You cannot hope to have a knowledge of the objects without affecting them, and the knowledge you get is incomplete and unreliable by virtue of the nature of the reality itself.

As far as "objective reality" is concerned, the implications of quantum mechanics is far more penetrating. It seems that objective reality is not that much "objective" as we used to consider in classical physics but rather, it's a joint product of the interaction between the subject and the object (i.e. the reality "out there"). The world view of quantum mechanics is, unlike that of the classical physics, holistic. In this context, the following excerpt from the book 'The Ghost in the atom, a discussion of the mysteries of quantum physics' (Edited by P.C.W. Davis & J.R. Brown, Cambridge University Press.) will, in my opinion, help to conceive the implications.

"The physicist John Wheeler likes to tell a delightful parable which nicely illustrates the peculiar status of a quantum particle prior to measurement. The story concerns a version of the game of 20 questios :

Then my turn came, fourth tc be sent from the room so that Lother Nordheim's other fifteen after-dinner guests could consult in secret and agree on a difficult word. I was locked out unbelievably long. When finally being readmitted, I found a smile on everyone's face, sign of a joke or a plot. I nevertheless started my attempt to find the word. 'Is it animal?' 'No.' 'Is it mineral?' 'Yes.' 'Is it green?' 'No.' 'Is it white?' 'Yes.' These answers came quickly. Then the questions began to take longer in answering. It was strange. All I wanted from my friends was a simple Yes or No. Yet the one queried would think and think, yes or no, no or yes, before answering. Finally I felt I was getting hot on the trail, that the word might be 'cloud'. I knew I was allowed only one chance at the final word. I ventured it : 'Is it cloud?' 'Yes,' came the reply, and everyone burst out laughing. They explained to me that there had been no word in the room. They had agreed not to agree on a word. Each on questioned could answer as he pleased—with the one requirement that he should have a word in mind compatible with his own response and all that had gone before. Otherwise, if I challenged, he lost. The surprise version of the game of twenty questions was therefore as difficult for my colleagues as it was for me.

What is the symbolism of the story? The world, we once believed, exists 'out there' independent of any act of observation. The electron in the atom we once considered to have at each moment a definite position and a definite momentum. I, entering, thought the room contained a definite word. In actuality the word was developed step by step through the questions I raised, as the information about the electron is brought into being by the experiment that the observer chooses to make ; that is, by the kind of registering equipment that he puts into place. Had I asked different questions or the same questions in a different order I would have ended up with a different word as the experimenter would have ended up with a different story for the doings of the electron. However, the power I had in bringing the particular word 'cloud' into being was partial only. A major part of the selection lay in the 'yes' and 'no' replies of the colleagues around the room. Similarly the experimenter has some substantial influence on what will happen to the electron by the choice of experiments he will do on it, 'questions he will put to nature' ; but he knows there is a certain unpredicatability about what any given one of his measurements will disclose, about what 'answers nature will give', about what will happen when 'God plays dice'. This comparison between the world of quantum observations and the surprise version of the game of twenty questions miss much but it makes the central point. In the game, no word is a word until that word is promoted to reality by the choice of questions asked and answers given. In the real world of quantum physics, *no elementary phenomenon is a phenomenon until it is a recorded phenomenon.*"

5. IN LIEU OF A CONCLUSION

The concept of an experiment forms the basis of scientific cognition. It was the basis of scientific cognition for the classical i.e. Newtonian mechanics, it still forms the basis while classical physics has given way to quantum physics. But the role of experiment in the scientific cognitive process has changed dramatically. Any act of observation splits the world into two entities viz. the observed reality, and the observer. So far as classical physics is concerned, the act of observation has no significant influence on the observed phenomenon so that the observation may be considered to be an authentic picture of reality. Classical physics also assumes that the outcome of the experiment is not dependent on the act of experimenting, in short, classical physics presumed the objective nature of reality 'out there'. Quantum mechanics, however, proved that though these assumptions are convenient to work with the macroscopic world, when the microscopic world of subatomic particles are concerned they are grossly inadequate. Heisenburg's uncertainty principle ruled out the possibility of making delicate measurements with an arbitrary accuracy so that it seems that nature cannot be investigated beyond a certain limit by virtue of the laws of nature itself. Moreover, the concept of a classical 'objective' reality has been renewed by making it clear that, at least in the microscopic world of subatomic particles, the observer also takes part in the occurrence of a phenomenon. The subject, thus, is an integral part of reality as a whole in the sense that the subject and the object are not entirely independent of each other.