The Scientific Enterprise

5. Some Characteristics of Scientific Knowledge

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Kinds of Knowledge

We recall that etymologically the word *science* means *knowledge*. But we can have all kinds of knowledge. For example, I may know that my friend Krishnan lives in Madurai, or that Delhi is the capital of India, or that my neighbor's dog barks every morning. We do not regard these as scientific knowledge. On the other hand, if we are told that all metals expand on being heated or that things thrown upwards fall back to the ground, that sounds like scientific knowledge. We may therefore raise the general question as to what exactly constitutes scientific knowledge, and what does not.

Here we may recall that ancient Hindu thinkers made a distinction between two types of knowledge, as expressed, for example, in the *Mundaka Upanishad* (I.4) where it is stated: Two kinds of knowledge are to be known, as the knowers of Brahman declare: the higher (*pará*) and the lower (*apará*). (*dve vidye veditavye iti ha sma yad brahmavido vadanti, pará caiváparáca.*) The Vedas, phonetics, rituals, grammar and the like belong to the lower category, while that which cannot be grasped, "which is eternal, omnipresent, and super-subtle" is the undecaying higher level. From this perspective scientific knowledge belongs to the *apará* category. In the Western tradition the *pará* type of esoteric knowledge is known as *Gnosis*.

It should be stated at the outset that the problem of the nature of knowledge is a very difficult and complex one in philosophy. From Plato and the Upanishadic seers to Immanuel Kant, Karl Popper and others, philosophers have defined and disagreed on the nature, reliability, sources, and uncertainty of human knowledge in general. Some have tried to define knowledge, others have declared this to be a futile exercise; some have equated knowledge with belief and others have drawn subtle distinctions between the two; some have argued that correct knowledge of anything is beyond human capabilities, yet others have maintained that reason and rationality are certainly not the only means by which true knowledge may be attained; some have distinguished between knowledge of things and knowledge of truths, others have said that direct evidence is unnecessary for certain kinds of knowledge; some have suggested that the human mind can acquire some types of knowledge about the external world without directly interacting with it, while others have declared that this is impossible. Suffice it to say that if one is interested in this very interesting and multi-faceted field of inquiry (called epistemology) one should refer to works on philosophy: this will have the effect of experiencing confusion on the subject, but from sophisticated perspectives. A good introduction to the subject may be found in Clare Hay's *The Theory of Knowledge: A Coursebook* (2008).

However, here we will not be concerned with the problem of knowledge at a technical metaphysical level. Because of the limitation of our sense perceptions and the finiteness of our experiences, what we think we know may not be the total and absolute truth. Having made this general statement, we will also assume that at least one type of knowledge, perfect or imperfect, is available through our sense perceptions and rational faculties. And it is this kind of knowledge that science considers. In this context, by knowledge one means any awareness and understanding that one has gained from a facet of our experience resulting in either intellectual satisfaction, explanatory confidence, and/or a capacity to solve a practical need or problem. We are talking about knowledge that is of some of value to the mind or the body.

Now let us explore some of the characteristics of scientific knowledge.

Communicability

Science is not a personal view, it is a collective enterprise. Hence scientific knowledge must be communicable. Knowledge is generally communicated through language. However, not every piece of information may need language for communication. For example, one can reveal feelings of anger, love, contempt, or sympathy without the explicit use of words. Conversely, not every piece of information that is communicated through language may be fully effective. For example, no matter how descriptively a woman verbalizes her experience of giving birth to a child, it will be impossible for a man or for a woman who has not had a child, to grasp it. "I know where my shoe pinches" is another example of a piece of information that simply cannot be meaningfully or fully conveyed through words alone.

Mystics have reported aspects of the external world of which they claim to have become aware from intense, non-communicable experiences. They speak of the ultimate nature of reality in terms which, they admit, do little justice to it. The contention that there are external, objective features of the world which one may recognize, but which cannot be transmitted verbally or symbolically, would be unacceptable to most scientists. The reason for this is that science deals with aspects of the world which are amenable to verbal, logical, and mathematical analysis, and can be meaningfully involved only in those aspects of the real world to be so amenable. This is not to deny the existence of deeply personal experiences, but to say that they are beyond the scope and interest of science if they cannot be communicated to others. Communicability is a necessary feature of all scientific knowledge.

Systematic Organization

G H Lewes described science as "the systematic classification of experience". Scientific knowledge always forms part of, and often results from, the ordering and systematizing of facts of experiences. But science does not result from mere organization of information. Neither a library catalogue nor a telephone directory may be regarded as an example of scientific knowledge. Systematization of data certainly serves as a useful step towards the elucidation of relevant information. Since in the scientific enterprise one tries to detect patterns in a maze of phenomena, one can see its value in this context. The sciences of planetary motions, of atomic spectra, of chemical substances, of botany, of elementary particles, all have been enriched and have advanced from the systematization of empirically derived data.

Conversely, all scientifically acquired knowledge is put in well-organized and readily accessible formats. The prime examples of such presentations are to be found in various textbooks, handbooks, and encyclopedias of science. Ironically, the work-tables of many scientists tend to be rather cluttered and may strike an observer as somewhat disorganized!

Generality

Scientific propositions are general rather than particular. A stone thrown upwards in the air falls back to the ground. So does an apple, a book, or a hammer. But these statements of observed facts do not constitute scientific knowledge. The proposition that "all bodies when flung upwards in the air will fall back to the ground" is an item of scientific knowledge. Similarly, we know that copper expands upon heating. So do silver, mercury, and iron. These descriptions of particular metallic behavior may be generalized into the scientific proposition that "all metals expand on heating".

Generalization is one of the principal goals of science. Its importance lies in the fact that it reveals to us in a compact way a specific pattern of behavior of nature. Thus, generalization explains the particular phenomena that are observed. If we are aware of the general proposition that all planets move around the Sun in elliptical orbits, we feel we have explained why a newly discovered planet, say Pluto, also has an elliptical orbit.

We may note in passing that science differs from literature in this regard. Literature is the exemplification in various specific contexts of general truths. For example, when two young people meet and fall in love, there are likely to be hurdles in the fulfillment of their love. This is a general statement about the human condition, and is of little interest to us. However, there are countless love stories that illustrate this general principle. Every good literary narrative reflects some fundamental truth or truths.

Possibility of Universal Agreement or Disagreement

For a proposition to be of scientific interest, it must be capable of leading to universal agreement as to its validity or otherwise. That is, people in different places and at different times must be able to examine the content of the statement independently, and arrive at some consensus on it. It is not necessary that everybody should eventually agree that the statement in question is correct. But what is required is that it must be possible, in principle, to envisage conditions under which there can be universal agreement as to the truth value of what is stated.

In the middle of the nineteenth century it was suggested that there was a planet closer to the Sun than Mercury. This could be taken as a serious scientific statement because not only was there some basis for suspecting the correctness of the conjecture, but there was also, in principle, the possibility of detecting it, if it existed. In fact, such a suggestion was made during the l9th century (Richard Baum and William Sheehan, *In Search of Planet Vulcan, The Ghost in Newton's Clockwork Machine*, 1997). Even a name was proposed for this hypothetical planet (Vulcan) by Jean Joseph Le Verrier, one of the discoverers of the planet Neptune. Edmond Modeste Lescarbault claimed to have discovered that hypothesized planet, and several other astronomers confirmed it. But today astronomers have generally abandoned the idea of Vulcan.

Now consider the statement that Ravi Varma is the greatest painter that ever lived. There can never be universal agreement or disagreement on this, for the simple reason that people's evaluation of art always involves some elements of subjectivity. It is therefore inconceivable that every connoisseur will proclaim any one artist – Jean Renoir or Ravi Varma or whoever – as the greatest one that ever lived. Indeed, there may be dissenters even to the more restricted proposition that such and such a one was a great artist.

Similarly, statements like: Communism is the best (or worst) form of government; Roman Catholicism is the best (or worst) religion, Indians are the most non-violent people, can never attain universal consensus. However important and convincing such statements might seem to individuals or groups, such declarations cannot be regarded as scientific knowledge.

The question that arises then is the following: How can one determine whether or not a given proposition is capable of leading to universal agreement? Thus, for example, how can we be sure that some day Voodoo will not be declared by all humankind as the best (or worst) of all religions? Or, on what basis can we assert that some day all scientists will agree on the existence or otherwise of particles that move faster than light?

It is very difficult to be absolutely certain on such matters. However, it is possible to formulate rough rules concerning the likelihood of one or the other. Generally speaking, propositions resulting from the emotional likes and dislikes of individuals, or which have their source in social, cultural, religious, or personal factors, most probably will never lead to universal agreement. Thus, any historical assertion that touches one's national pride is unlikely to be based on purely scientific knowledge. Similarly, one may say with some degree of certainty that propositions which provoke objections on purely intellectual, factual, and conceptual grounds, can lead to universally acceptable judgments as to their validity or otherwise.

At any phase in the history of science there are two levels of science which may be described as *classical* and *current*. Classical science consists of results and worldviews which are universally accepted by the scientific establishment of the time. There could be a few dissenters, but they have usually not contributed enough of significance to improve upon the issues they are unhappy about. In the case of physics, by convention one refers to all the physics between the mid-sixteenth and end-nineteenth century (i.e., the physics that was developed prior to the rise of quantum mechanics and relativity theory) as classical physics.

Current science consists of the countless unsolved questions and problems which engage research scientists at a given period. Here competing, sometimes conflicting, views and theories are presented (in meetings, technical journals, symposia, etc.). These are received and analyzed, extrapolated and explored further, by members of the scientific community, usually experts in particular fields. The process goes on and on until some consensus is reached, and a tentative scientific theory then becomes a classical result. There is no guarantee that a result of classical science will remain stable: i.e., will continue to be accepted by the scientific establishment and taught in schools and colleges, indefinitely. Every scientific worldview is potentially unstable.

Each individual scientist and often his/her school, i.e., fellow scientists who work along the same lines, do research, and present their results to fellow scientists in the field, keep publishing their ideas until these are overwhelmingly convincing compared to rival ideas.

At the stage when one puts forward a new idea in science it may sometimes be ignored by the scientific establishment. Then one may feel frustrated with the whole system. Unfortunately, the only recourse one has is to keep tirelessly submitting the results to peer-reviewed journals, in international meetings, etc., until they gain attention.

Disappointed and disgruntled scientists – and outside speculators, even more so – sometimes feel that their ideas are ignored or marginalized because of prejudice and close-mindedness on the part of mainstream science. Such ignoring does happen sometimes. However, this is not so much a question of prejudice. At any given time, there are many competing theories to answer unsolved problems. There is no such thing as private science, but there are separate groups trying to answer the same difficult questions. Generally, those who present ideas which have no connection with empirically observed or observable data are the ones who are ignored by mainstream science.

This is how, by and large, science has been developing during the past four centuries. Many good, insightful, and fruitful ideas have been ignored for a long time because of many factors, sometimes because they emerge from a little known outsider to the group, sometimes because of the vested interests of some members of the scientific establishment (their own theories may be in danger), or because of the inability of older scientists to fully absorb or understand revolutionary new ideas. Eventually, good ideas and solid results find their way into classical science one way or another. As Max Planck expressed it (*Scientific Autobiograhy*, 1968 ed.) somewhat bluntly, "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it".

It is equally true that many crackpots and quacks have complained that their great ideas were ignored by narrow-minded mainstream science. Usually, though not always, these people don't present convincing evidence or data for whatever they claim, and often they repeat what the ancients have said, trying to re-introduce ideas that proved ineffective for more than 2000 years.

To summarize, then, scientific propositions may be broadly divided into three categories: (a) those on which universal agreement has been reached, i.e., those which are currently considered to be beyond question by the scientific community at large; (b) those that have been tested and rejected as unacceptable; and (c) those which are potentially capable of reaching the status (a). The hope of every new scientific proposition is that it will become part of classical science sooner or later. However, it must be realized that even after a scientific proposition has moved into the category of classical science, there is still no guarantee that it will remain there for ever.

Relation to Other Knowledge

A scientific proposition never stands by itself. It always bears some relation to other items of knowledge. This is because science is a body of knowledge, an integral and interconnected whole, not just a heap of piecemeal information. Claude Bernard put it pithily (*An Introduction to the Study of Experimental Medicine,* 1865) when he said, *l'art c'est moi, la science c'est nous*: Art is me, science is we.

A poem or a *keertanam* may stand out as an entity by itself, totally independent of other such compositions, as the creative product of a single individual. But this is never the case with scientific results. Scientific knowledge invariably has a context and a relationship. Its very formulation or discovery would be impossible without other previous work. Consider, for example, the following statements:

Water boils at 100 degrees celsius.

The electron is a negatively changed particle.

This journal has more than 50 pages.

The first of these propositions implies a definition of temperature and of a scale.

The second is related to the concept of the electric charge. The third, however, could stand all by itself. It is totally unrelated to anything else that may be regarded as scientific knowledge. The first two are scientific propositions and the third is not.

Insight into the Nature of Things

Scientific knowledge generally provides us with some understanding of natural phenomena. A piece of information which tells us something new, but which gives us little or no insight into some aspect of the world would not be part of science.

Consider, for example, the statement that the sky is blue. However true this may be, it is not quite an item of scientific knowledge. On the other hand, if there is some discussion of what causes the sky to be blue (such as the scattering of light), we are entering the realm of science. The purpose of science is not simply to inform, but to also reveal hidden truths about the world. That white light is a composite of the rainbow-colored lights can be seen with the aid of a simple prism. But that it consists of waves of different frequencies is scientific knowledge. Information can be furnished in single, simple, unconnected phrases. But understanding involves a thread that weaves all the information into an integral whole. Hence scientific propositions seldom appear alone.

That bodies fall down to the ground is not scientific knowledge. That they do so due to a force exerted by the earth, is. That we can hear a noise in another room is not scientific knowledge. That this is possible because of the diffraction of sounds waves, is.

Concluding Thoughts

These characteristics of scientific knowledge should be recognized by those who imagine they are talking science when they are only making poetic statements about the world which have no connection to the scientific worldview. Thus, statements to the effect that lying down to sleep along certain directions will assure good health, that if matters are not initiated within certain time intervals disasters would ensue, or that morally and spiritually uplifting episodes in sacred history are of the same category as historical events, may have traditional and even placebo values, but they are not part of scientific knowledge. This is not to underestimate their significance for culture and custom but to recognize the role and relevance of different kinds of knowledge.

Here we may distinguish between scientific, trans-scientific, and unscientific propositions. A scientific proposition adheres to the criteria we have discussed above. A trans-scientific proposition has no relation to science, and yet may be interesting, uplifting, psychologically satisfying, culturally enriching, and quite meaningful in life. An unscientific proposition blatantly contradicts basic science, and can only cut an awkward figure in the scientific world if it is claimed to be scientific. To say that a Divine Being gave rise to the world is trans-scientific, but the claim that the planet Saturn caused the last stock market crash is unscientific.

Understanding the difference between science, trans-science, and unscientific claims is important not only for science but no less in other contexts in life. In the absence of such demarcation many profoundly meaningful trans-scientific beliefs are rejected by so-called rationalists as nonsense, when, in fact, a good many trans-scientific beliefs are at the foundation of human cultures and civilizations. On the other hand, unscientific absurdities are propagated as scientific truths to millions of people all over the world.

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[*] Part 1. Science: Some Definitions and Views, *Resonance*, Vol.13, No.6, pp.596–605, 2008.
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