SCIENTIFIC ATTITUDE AND DEVELOPMENT IN SCIENCE AND TECHNOLOGY*

Jayant Vishnu Narlikar**

Prof. Jayant Vishnu Narlikar is an Indian astrophysicist, known for giving the conformal gravity or the Hoyle–Narlikar theory. He worked on some important problems of astronomy, including gravitational collapse and a new theory of gravitation. He has received many national and international awards and accolades including the Padma Vibhushan. Apart from his contribution through research work, Prof. Narlikar is well known as a communicator of science through his lectures, books, articles and radio and television programmes. He currently serves as an Emeritus Professor at the Inter-University Centre for Astronomy and Astrophysics.

The paper is an excerpt from the Jawaharlal Nehru Memorial Lecture delivered by Prof. J. V. Narlikar in New Delhi on 13 November, 1976 on the topic "The Role of Scientific Outlook in Development of Science and Technology." In his lecture, Prof. Narlikar emphasises upon the essence of the scientific process and approach. Narlikar highlights the importance of creativity and originality in science. By providing the example of historical context of planetary motion, he talks about how with empirical evidence, scientific outlook replaced supernatural explanations. He addresses the revisability of scientific laws, using Einstein's Special Theory of Relativity as a case where new theories emerged from experimental conflicts with established laws. Narlikar also discusses the conservative nature within the scientific community and the challenges posed by new discoveries. He critiques the presence of superstitions and the common man's reliance on miracles and advocates for a rational, questioning attitude. Narlikar underscores the role of science in addressing societal issues, quoting Nehru's belief in science as a solution to problems like hunger and poverty. The importance of basic research and the need for a scientific outlook in developing nations is emphasised, citing Dr. Homi Bhabha's views on the value of fundamental research for societal progress. He concludes by reflecting on the limitations of human understanding in science, suggesting that current knowledge may be incomplete and hinting at future breakthroughs.

Keywords: Scientific Attitude, Solar System, Planets, Gravitation, Theory of Relativity, Basic Research

Writing to his daughter about the quest of man, from the Gaol District in Dehradun on 10th June, 1932, Nehru had this to say:

"Science gives a doubting and hesitating reply, for it is of the nature of science not to dogmatise, but to experiment and reason and rely on the mind of man. I need hardly tell you that my preferences are all for science and the methods of science."

Thoughts like these were to prove important for the growth of the newborn nation in 1947. They continue to be important to us today.

The Scientific Approach

School children learning science are told that a scientific investigation consists of three steps: the experiment (E), the observations (O) and the deduction (D). This particular pattern of investigation has emerged after centuries of practice of science; and the scientific outlook that I want to talk about lies somewhere at the bottom of it. Its origin lies in the questions "What?", "How?" and "Why?" that man put to himself and tried to answer. Each answer gave rise

*First published in Vol. 14(4), Dec 1976

**On November 13, 1976 Prof Narlikar delivered the Jawaharlal Nehru Memorial Lecture in New Delhi on "The Role of Scientific Outlook in Development of Science and Technology." The paper is an excerpt from this lecture.

to many more questions. While a correct answer closed one particular subject, it at the same time opened up several new ones. And this proliferation of questions and answers has led to the vast and expanding field of science that we see today.

Let us see how the E–O–D process operates in science. As mentioned above, its beginning lies in some question about nature, let us say, about a certain phenomenon seen to occur in our physical world. The experimental part now comes in. The experiment is set up to observe the phenomenon in several different ways. The experimenter can, in many cases, alter the various operating conditions, to enable him to study the outcome in as many situations as possible. Another object of such experimentation is to eliminate the human element as far as possible and make the results objective.

The next step of observation is not as straight forward as it may sound. The result of the experiment may be qualitative or quantitative. In the latter case the scientist ends up with a set of figures. Before any deductions can be made, it is often necessary to detect a pattern in the observed results, and this is where the so-called signal and noise come in. Here 'signal' represents the pattern which one is looking for against a background of a maze of data, called the "noise." The analogy of a specific sound signal against a noisy background is quite clear. How does one extract the signal? The human eye of an experienced experimenter is very often able to detect this. There are cases, however, where this is not possible and help must be sought from the statistical methods of data analysis. Recourse to statistical methods is in any case desirable to ensure objectivity. Unfortunately, there are situations where even statistical methods are not able to give unambiguous answers. The scientist must then design, new and better experiments.

The last step in this process is that of deductions. The scientist is not satisfied with drawing the conclusion for the one experiment he has just performed. He is interested in making predictions for other situations not covered by his experiment. The purpose of this exercise is to prompt future scientific experiments to be designed to test these predictions. His own experiment may also have been done to test the prediction of a previous scientific theory.

This interplay between theory and observations is what keeps science going. Without scientific theories to guide him, the experimenter will not know exactly what to observe. Indeed, the modern scientist knows that no scientific theory will be entirely correct. Sooner or later some new experiment will be designed which will disprove some crucial prediction of the theory. But eventually a new, enriched order emerges.

Thus the disproof of a well established scientific theory is regarded as a very exciting event by the scientist. It was in this connection that Sir Hermann Bondi, the well-known astronomer, remarked:

> The essential thing in science is for the scientist to think up a theory. It always requires human imagination, and indeed in science we pay the highest respect to creativity, to originality. It is, of course, clear that since every theory must live dangerously the casualty rate is pretty high. So we do not honour scientists for being right. It is never given to anybody to be always right. We honour scientists for being original for having started a whole

line of work. Science is the most human of endeavours because it depends on co-operation, it depends on people testing each other's work and it depends on people taking notice of each other.

—from Cosmology Now, Ed. L John, 1973, B.B.C. publications

It is against this background that one must see what is meant by the scientific outlook. Although it arose out of the development of science it has proved useful to the conduct of human affairs in a wider context. Nor is the scientific outlook necessarily confined to those who practise science. An uneducated (person) may be endowed with it whereas a professional scientist may be devoid of it! We will now look at some examples of how this outlook influenced the growth of science.

The Motion of Planets

From time immemorial man has looked at the clear night sky and wondered what the heavenly objects were supposed to be. He must have compared and contrasted their appearance with that of the sun during the day. From where does the sun appear in the East and where does it go in the West?

Now, there is a tendency in the human mind to ascribe strange natural phenomena to supernatural causes. This tendency runs counter to the scientific approach which is born out of curiosity and thrives on a critical assessment. We see an excellent example of the two tendencies in man's approach to the motion of heavenly bodies. Man ascribed supernatural powers to the sun, the moon and the stars. Those with the irregular motions were singled out as having greater power because their irregularity implied that they could move across the sky "at will." These are none other than the planets of our Solar System. From this to argue that these "powerful planets" control human destiny. We could understand and sympathise with this view, shared by most primitive cultures, more than two thousand years ago. But today, when the scientific approach has provided the answers, the situation should be entirely different.

How the scientific outlook prevailed and led to the solution of the mystery is an interesting story. Among the primitive cultures records were kept of the positions of some important heavenly bodies. The reason for these records was primarily utilitarian. For, man had learned to connect the changing of seasons with the changing positions of these objects in the sky. Since agriculture was strongly dependent on seasons, it was necessary to forecast these, and this is where the primitive astronomical observations helped.

Looking at these records, a curious few began to wonder whether there was any rule or pattern which controlled the motion of stars and planets. The pattern in the case of stars was discerned without much difficulty, but the planets posed more difficulties.

This hard problem was solved, according to the present records available, by the Greek astronomers (who) flourished before Christ. These astronomers gave elaborate geometrical construction involving circles, called the epicycles, to describe how planets move when observed from the Earth. With this epicyclic theory they were able to predict where each planet would be at a given time with reasonable accuracy.

To have detected order beneath the chaotic motion of planets was a feat of high intellectual order. For several centuries the description of planetary motion as given in Ptolemy's book "Almagest" was accepted in toto. Indeed, it had achieved the status of religious dogma (Yet, it was challenged in the sixteenth century).

The central hypothesis of Greek astronomy was that the Earth was a fixed object in space around which the heavenly bodies moved. (In 1473), Nicolaus Copernicus argued that the description of planetary motion became simplified if the sun was taken as the fixed object. He went on to give his own geometrical constructions to demonstrate this.

In this, Copernicus did not achieve any significantly better accuracy than Ptolemy. But his picture is considerably less complicated. Moreover, by pointing to the sun as the centre-piece, he initiated the next important step: Why do planets move round the sun? Thanks to the investigations of Kepler, Galileo and Newton, the answer to this question finally emerged. It was Isaac Newton's law of gravitation which accounts for this motion.

We can now contrast the scientific outlook with the superstitious approach to natural phenomena. The view that planets exert influence on human destiny still persists, although the original basis for it is gone. Thanks to space technology, man is now on the way to landing scientific instruments on these planets. It should be remembered that the remarkable accuracy of the Viking landing on the planet Mars would not have been possible without a confident application of the laws of science tested through the process of E-O-D.

Are Scientific Laws Subject to Revision?

Are the laws of science, as discovered by the above E-O-D method, sacrosanct and unchangeable?

In principle, the answer to this question is "No". A scientific theory or law is acceptable only so long as it fulfills the criterion that it explains—or at least does not conflict with—any phenomenon observed in nature. Once it fails to satisfy this criterion, it must either be modified or totally rejected.

If a law has been well established for long, but encounters a conflict with a series of experiments, the scientist will resort to a revision of the law only when everything else has failed. This "everything else" may include new experiments, a different interpretation of the same law, and sometimes a very far-fetched set of assumptions.

The classic example is the advent of Einstein's Special Theory of Relativity. Towards the end of the last century an experiment on light propagation by Michelson and Morley produced results which simply could not be accounted for in terms of Newtonian physics. The experiment attempted to measure the Earth's motion relative to a hypothetical medium called "the aether". Several attempts to measure this motion (failed). No motion was detected.

Many experienced theoreticians, including Lorentz, Fitzgerald, Poincare and others, attempted to account for this within the existing framework of (Newtonian) physics, but they were not successful. It was not until 1905, when Albert Einstein proposed his revolutionary Special Theory of Relativity that this riddle could be solved. It involved a radical departure from the Newtonian ideas of space and time.

Today Einstein's Special Theory of Relativity is an accepted part of science. Yet its acceptance by the scientific community was not (easy). Most leading scientists viewed it with suspicion.

Special relativity dealt one blow to the complacency of the nineteenth century science. Quantum theory dealt another. The scientists of the last century, especially after the highly successful electromagnetic theory put forward by Maxwell about a hundred years ago, had been gradually coming to the view that most of basic physics was already known and that only details needed to be worked out. This view came in for several shocks; while the classical laws of science predicted a continuity in the behaviour of natural phenomenon, those on the atomic scale showed a discrete or a "jumpy" behaviour. Nothing of the classical physics seemed to fit .The special relativity and the quantum theory together represent the triumph of the scientific outlook in the development of science;it is also a triumph over the innate conservatism of the scientific community.

This conservatism of the scientist is his tendency to seek shelter in the established ideas. In spite of his declared aim of "objectivity", he tends to be hostile to any new theory or interpretation .

In astronomy today this problem is being increasingly felt. Thanks to the rapid growth of technology after World War II, the astronomer has several new tools at his disposal to probe the universe.

He is discovering new and weird phenomena in the remote corners of the universe.

Some of these he can interpret by clever extrapolations of his scientific knowledge gained in the terrestrial laboratory. But there are many others which defy explanations. How should one approach these apparently insoluble problems?

Speaking in this connection in the 1970 Vatican Conference, Sir Fred Hoyle, a leading astrophysicist of our time, remarked :

> I think it is very unlikely that a creature evolving on this planet, the human being, is likely to possess a brain that is fully capable of understanding physics in its totality. I think this is inherently improbable in the first place, but even, if it should be so, it is surely widely improbable that this situation should just have been reached in the year 1970.
>
> —Study Week on Nuclei of Galaxies, Ed. O'Connell (North Holland)

There are some who would join issue with Sir Fred and argue that nothing discovered so far requires a modification of the existing laws of physics. To me such an attitude seems dangerously close to the point of view of scientists of a century ago, which I mentioned earlier.

My own personal view is that we may already be seeing evidence in astronomy that our laboratory based knowledge of physics is incomplete and I will illustrate this point of view by hazarding a guess as to where the break-through may come.

The Law of Gravitation

In describing the history of man's efforts to understand the motion of the planets, I had stated that the law of gravitation given by Isaac Newton successfully accounted for this motion. This law is simple in its statement but profound in its implications. I will concentrate on one particular feature of it. This is the strength of gravitational attraction. This strength is characterised by the constant of gravitation, usually denoted by the letter G. The force of attraction between two masses m_1 and m_2 separated by a distance r is then given by the simple formula:

$$\frac{Gm_1m_2}{r^2}$$

Thus the bigger the masses, the larger is their mutual attraction and the further apart they are the less is this force. In the terrestrial laboratory we deal with relatively small masses and so this force is negligible compared to other for around, such as electricity and magnetism. But the situation is quite the opposite in astronomy where we deal with enormously large masses. The mass of the sun is some 2 million million million million million kilograms. Our Milky Way system is estimated to be hundred thousand million times as massive as the sun. There are strong region galaxies even more massive the our Milky Way. The question is, "does the law of gravitation operate for such systems in the same way as it does for the sun and the planets?" The astronomer works on the assumption that it does. But already there are indications that he may be wrong in making this assumptions.

A related question is "does G remain a constant or does it change with time?" Newtonian gravitation implicitly assumes that G is a constant. (In the) general theory of relativity (given by Einstein in 1915), this assumption (is made) even more strongly. What do astronomical facts say?

Recent use of accurate atomic clocks has made it possible for astronomers to check whether G is constant or changing with time. In principle, observations of the earth and the moon should tell us something about this. For, if G is slowly decreasing with time the moon will gradually move away from the earth and go round it more slowly. The present observations indicate that this may be happening although very slowly. If at all, G may be decreasing by a few parts in a thousand million per century. It is too early to be definitive about this conclusion since it has profound implications for the well established theories of Newton and Einstein. Even if it turns out to be correct, its acceptance by a basically conservative scientific community will take some time.

The Scientific Outlook in Daily Life

I have given these examples from the history of science and from modern science to illustrate how the scientific outlook has been responsible for whatever progress science has made to date. However, the scientific outlook need not be the prerogative of the scientists alone.

Indeed, just as in the case of science, progress could be achieved only when the scientific outlook prevailed over the innate conservatism, so in the case of a society of human beings this outlook acts as an antidote to the evils of prejudice and superstitions.

Superstitions are born out of ignorance of how nature functions. Science is dedicated to the unravelling of the mysteries of nature. As one particular mystery is solved, we should expect the superstitions based on it to disappear. Yet, this does not always happen in practice.

Now that astronomy has answered most of the questions raised about planets by the primitive man, we should expect (the related superstitions) to (vanish). Yet this has not happened. Even in the technologically advanced country like the United States (as) recently as a year ago, a group of 186 leading scientists were signatories to a circular denouncing the (divine power ascribed to planets).

I give below an extract from their statement:

> It is simply a mistake to imagine that the forces exerted by stars and planets at the moment of birth can in any way shape our futures. Neither is it true that the position of more favourable to particular kinds of action, or that the sign under which one was born determines one's compatibility or incompatibility with other people. In these uncertain times many long for the comfort of having guidance in making decisions. They would like to believe in a destiny predetermined by astral forces beyond their control. However, we must all face the world, and we must realize that our futures lie in ourselves, and not in the stars.
>
> —The Humanist, Sept. Oct. 1975

Suppose a scientist is asked to examine this question: "Do planets influence human destiny?" How will he go about testing the hypothesis? He will not be satisfied by the prediction by a single person based on a single horoscope. First, he will require a set of well-defined rules on which such predictions are based. The rules should be unambiguous so that different persons make the same prediction from the same horoscope. Next he will need to be convinced that these rules work in a statistically significant manner to discount the possibility of the prediction being right purely by chance. This will require a systematic study of a large number of cases under different conditions.

Let me give a simple example, suppose someone claims to predict with reasonable accuracy whether a tossed coin will fall with "head" up or "tail" up. Will a single toss decide the truth of his claim? We all know that any one can predict correctly the outcome with 50 per cent accuracy. This chance element must somehow be reduced. Suppose we ask him to perform this prediction-test 100 times, and he predicts correctly 50 times. Again we will argue that, this is not a significant indicator of his predictive power. But suppose he is accurate 51 times. Do we give him credit? What if he is accurate 70 times? The statistician has devised tests to decide whether the success achieved in a particular experiment is purely due to chance or due to some other factor. It is not always necessary to call upon the professional scientist to perform such tests. The educated common man can himself sift the evidence provided he adopts an objective outlook.

Of the scientific outlook in layman, I can think of no better example than that of James Watt. Seeing the lid of a kettle of boiling water being tossed out he began to wonder about the cause and so arrived at the power of trapped steam. This was the beginning of the technological revolution in England.

The Scientific Outlook Versus Traditions

India is a country with a long history of refined human culture. It has been, and it continues to be, the home of world's great religions. Its multi-language literature is rich in the thoughts of great thinkers.

Yet, it is up to us to derive the maximum benefit from this legacy. Do we merely stay contented that we had such a glorious past? Or do we heed and follow literally the views of our forefathers? Or should we pick up the essence of their wisdom and adapt it to the changing circumstances of today's world? To me it seems that by and large our present society is happily following the first two approaches and scarcely bothers to give a thought to the third one even though it appears logically the most important.

Let us take the case of Hindu religion. Its primary sources, the Vedas and the Upanishads, are said to be without authors. Yet whoever originated them, was (or were) moved by the spirit of rational enquiry which would have done credit to any scientist today. However, this desire to ask questions and seek answers seems to have got lost behind the multitude of meaningless rituals we see around today.

Let me illustrate this by giving an example. Suppose a (man) has to make a business trip on a certain day (which happens to be) inauspicious. What should he do? He cannot change the day of the trip for business reasons. So he looks for a loophole. On the previous day (which is not inauspicious) he goes out of the house and leaves some token item with a neighbour. He then returns to his house and goes on his trip the next day as planned. His visit to the neighbour is supposed to mark the beginning of his trip. So he has fulfilled his business obligation of the required day without beginning his trip on an inauspicious day. I present this example to you without comment.

Similar examples may be found in other religions. It is characteristic of all great religious thinkers and philosophers that their greatness is motivated by the same spirit of enquiry that drives the great scientists today. Yet, by the time their wisdom is transmitted to the common man, the original humility of the great men is forgotten. Instead their place is taken by the so-called demi-gods or miracle workers.

Partly the common man himself is to blame for this state of affairs. In his desire to avoid the hard work needed for success he is forever on the lookout for shortcut methods. The so-called "miracles" appear to him the ideal way to achieve his end.

Albert Einstein once said "In this materialistic age of ours, the serious scientific workers are the only profoundly religious people". The scientist is the last person to assert that he knows "all the answers". He is forever asking questions and searching for solutions. But he will not accept anything on trust—just because someone said so.

Unfortunately, the hard-headed scientist is yet to discover a "miracle" in his investigations of natural phenomena. After years of work he has arrived at certain "conservation laws" which are obeyed in Nature. These laws have precise mathematical formulations and accurate experimental verifications; A scientific investigation of the so-called "miracles" one hears of at present would be very rewarding, whatever its outcome. If the "miracles" are proved to be frauds, the society will rid itself of an evil. If they are proved to be genuine it would mean a great leap forward in the advancement of science.

The Scientific Outlook in a Developing Nation

Speaking some ten years before independence, Nehru had expressed the conviction that:

> Science alone can solve the problem of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people . . .
>
> —Jawaharlal Nehru, Frank Moraes, Macmillan

Indeed, at first sight, these problems before us appear to be formidable if not unsurmountable. Yet, we have only to look at the remarkable progress of science over the last few decades to see that a properly channelled scientific approach holds out hope for the future.

Unlike the so-called miracles I mentioned earlier, the miracles of science benefit not one single individual, but a whole class of humanity. You need pure scientists to do basic research, applied scientists to consider applications of science to human welfare and technologists to translate these concepts into reality. You also need educated people to acquaint the masses with what science has to offer and to create a climate in which the common man becomes interested in and receptive to the new ideas of science. The task of popularisation of science is a very important one.

The second important point is that we must not denigrate basic research. It would be a shortsighted point of view to argue that basic research is an expensive luxury which a developing country cannot afford. To elaborate this, I reproduce here an extract from the speech made by Dr. Homi Bhabha, the founder of the Tata Institute of Fundamental Research on the occasion of the inauguration of the new buildings of the Institute by Nehru:

> By fundamental research I mean basic investigations into the behaviour and structure of the physical world without any consideration, regarding their utility whether the knowledge so acquired would ever be of any practical value. Nevertheless, the support of such research and of an institution where such research can be carried out effectively is of the greatest importance to the society for two reasons. It helps to train and develop young men of the highest intellectual calibre in a society into people who can think about and analyse problems with a freshness of outlook and originality which is not generally found.

The developed nations have recognised these facts and they continue to encourage basic research. For us to ignore basic research at this stage would mean that we will have to keep on importing new ideas from abroad. Imagine a country which has vast untapped resources of oil, but which will not search for these for reasons of heavy financial outlay. Such a country will for ever be dependent on oil imported from abroad.

The developed countries are beginning to experience some of the ill effects of excessive and indiscriminate use of science and technology. We should try to avoid evils like pollution, drug addiction, the break-up of the family as a unit, when we seek to solve the existing problems with the help of science. Let us not end up as intellectual barbarians or technological savages, as the developed countries have been sometimes called. It is here, I think that we can draw on our rich cultural heritage—on the wisdom of our forefathers over many centuries.

I am optimistic that if we are not blinded by traditions and dazzled by science but keep our eyes open, our country will make a triumphant entry into the year 2001.