

Need for Scientific Temper

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A year ago I attended an international and inter-disciplinary conference dealing with the issues man has to face in the twentyfirst century. Naturally issues such as global environment, population control, food-availability, communications, education, science and technology, etc. featured prominently. As speaker after speaker covered a variety of topics of great relevance to the theme of the conference, I increasingly began to feel like a diner at a sumptuous buffet searching desperately for that tiny but vital item, namely, the salt shaker. By that pinch of salt I mean the scientific temper that is such an essential component of man's mental framework in his struggles to face the challenges of the present and the future. In this article I will discuss my own brief presentation on the subject at the conference along with certain other wider issues.

What is scientific temper? Why is its relevance being felt *now* rather than in the past? Is it an individual trait or does it also extend to societies, cultures, civilisations? To what extent is it prevalent today? What can be done to make it more widespread?

These are the questions I shall try to answer. But the bottom line has been stated much more effectively more than half a century ago by Pandit Jawaharlal Nehru:

The impact of science and the modern world have brought a greater appreciation of facts, a more critical faculty, a weighing of evidence, a refusal to accept tradition merely because it is tradition...

But even today it is strange how we suddenly become overwhelmed by tradition, and the critical faculties of even intelligent men cease to function... Only when we are politically and economically free will the mind function normally and critically... (*Discovery of India*)

This was written during the British Raj. Today we live in a free India which is feeling its way towards economic prosperity. Yet we are still a long way away from achieving that scientific outlook which is so essential for our future well-being.

School children learning science are told that

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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. Science itself arose out of man's curiosity about Nature. Its origin lies in the questions "What?", "How?" and "Why?" that man put to himself and tried to answer. Each answer gave rise 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 had led to the vast and expanding field of science that we see today. Alexander, before he became 'Great', once complained that because of his father's conquests he would be left with no more worlds to conquer. I do not think that a scientist will ever be in that position in his battles to unravel the mysteries of Nature.

Let us see how the E-O-D process operates in science. As mentioned above, its beginning lies in some questions 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, or the so-called experimental parameters, 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 straightforward 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 deduction 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 the 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, of the proverbial needle-in-the-haystack type, 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 is then back to the drawing board designing new and better experiments.

The last, but by no means the least, step in this process is that by deductions, that is, drawing conclusions from the experiment. The scientist is, of course, not satisfied with drawing the conclusion from the one experiment he has just performed. He is interested in making predictions for other situations not covered by his experiment, as for example, for situations beyond the range of his present experimental parameters. The purpose of this exercise is to prompt future scientific experiments to be designed to test these predictions.

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. It is only when the theoretical scientist tells his experimental counterpart some of his predictions that the latter can design suitable ways of testing them. Nor can the theoretician work in isolation forever. Unless he produces scientific predictions which can be experimentally tested, his theories will be considered sterile.

Littered with Sterile Knowledge

The history of science is littered with sterile theories and theories which were ultimately proved to be wrong. It is necessary to make a distinction between the two types. The former types, without any observable predictions, did not contribute to the growth of science. The latter types may have been considered viable for a while and prompted experiments which eventually led to their disproof. But, in this process, the scientist was also able to advance his knowledge.

Indeed, the modern scientist knows that no scientific theory, however right it may seem to be at present, will be entirely correct. Sooner or later some new experiment will be designed which will disprove some crucial prediction of the theory. For a while this may lead to an apparent

breakdown of law and order in the regime of science; but experience has shown that a new enriched order eventually emerges. Thus the disproof of a well-established scientific theory is regarded as a very exciting event by the scientist. It means that Nature has considered man to have matured enough to appreciate yet one more of her bag of secrets! 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. There is no way of mechanising this process; there is no way of breaking it down into a science factory. 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 being stimulating, for having started a whole line of work. Science is the most human of endeavours because it depends on cooperation, it depends on people testing each other's work and it depends on people taking notice of each other. (*Cosmology Now*, ed. L. John, 1973, BBC Publications)

However, the scientific outlook need not be the prerogative of the scientist alone. After all, it owes its origin to human curiosity about Nature and as such every one of us, whether a scientist or not, is entitled to it. Indeed, just as in the case of science, progress could be achieved only when the scientific outlook prevailed over 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 because of the lack of scientific outlook in the typical human being. I give below one example.

The early human societies ascribed divine powers to planets. This assumption arose from ignorance of what planets are and how they move. Now that astronomy has answered most of the questions raised about planets by the primitive man, we should expect this assumption to be regarded as groundless. Yet this has not happened. Even in the technologically advanced countries this belief persists among sections of educated classes. In the mid-1970s a group of leading scientists in the West were signatories to a circular denouncing the very basis of this

belief. 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 distant heavenly bodies make certain days or periods 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 realise that our futures lie in ourselves, and not in the stars...(The Humanist, September/October 1975).

Suppose a scientist is asked to examine this question: 'Do planets influence human destiny?' How will he go about testing the hypothesis that the answer is 'Yes'? 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 to illustrate my point of view. 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 anyone can predict correctly the outcome with fifty 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 comes to our rescue here. He has devised tests to decide whether the success achieved in a particular experiment is purely due to chance or to some other factor (as for example, the ability to predict correctly in the above cases or the possibility of the coin being biased).

Negative Results

Likewise, tests have to be made of the above hypothesis about planets. Such tests as have been conducted so far by scientists have shown

negative results. But again, 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.

Let me give two illustrative examples of experiments of this kind conducted in the United States to test the scientific predictivity of astrology.

In the first test conducted by B.J. Silverman¹ who sampled the marriage and divorce rates in Michigan in 1967 and 1968. His sample was large, containing 2978 marriages and 478 divorces. Their birth charts were examined by astrologers who were asked to opine on whether the horoscopes matched sufficiently to lead them to conclude that the couple's marriage would be long lasting and happy. The astrologers (using whatever criteria they had) made out two lots, one with matching and the other with conflicting horoscopes. These 'predictions' were then compared with the actual state of marriages of these couples, some of whom were happily married while others had divorces, broken marriages, etc. It was then a simple matter to make a comparison between the actual and the predicted divisions of the sample. Rigorous statistical analyses demonstrated that there was no correlation between predictions and the actual results.

The second test carried out by French *et al.*² besides drawing a similar conclusion throws some light on the psychology of the individual who is attracted towards astrological predictions despite whatever scientific temper he/she may possess. This aspect is sometimes called the 'Barnum Effect', coming from the famous Barnum and Bailey Circus in the United States. The circus owner P.T. Barnum was once asked why his circus was so popular. He explained that the circus contained a variety of acts of which at least one would appeal to each and every individual who would, therefore, sit through the entire performance, despite getting bored by many of the other acts. Astrologers likewise quote their assessment for an individual in a vague but all pervasive form, such that at least a portion of it may be found appealing by the individual. A horoscope reading of this kind is known as the Barnum Interpretation (BI). A typical BI may be stated as follows:

You have a great need for other people to like you and admire you. You have a tendency to be critical of

yourself. You have a great deal of unused capacity which you have not used to your advantage. While you have some personality weaknesses, you are generally able to compensate for them. Your sexual adjustment has presented problems for you. Disciplined and self-controlled outside you tend to be worrisome and insecure inside. At times you have serious doubts as to whether you have made the right decision or done the right thing. You prefer a certain amount of change and variety and become dissatisfied when hemmed in by restrictions and limitations. You pride yourself on being an independent thinker and do not accept others' statements without satisfactory proof. You have found it unwise to be too frank in revealing yourself to others. At times you are extroverted, affable and sociable, while at other times you are introverted, wary and reserved. Some of your aspirations tend to be pretty unrealistic. Security is one of your major goals in life.

Now, the experiment consisted of 52 individuals whose birth particulars were given to noted astrologers for making up interpretations of the personality of the individual. Each person was then given three interpretations: (i) the one applicable to his/her birth chart, (ii) another one belonging to some other individual in the group, and (iii) the BI. All persons were then asked to rank on a scale of five the applicability of each interpretation to his/her own personality.

Almost invariably the BI turned out to be the most popular with an average rating of 3.69 out of five. The other two interpretations hardly differed, with (i) scoring 3.08 and (ii) 3.06. This means that the individuals were swayed by the Barnum effect and also there was no distinction between 'genuine' and 'false' horoscopes readings!

I could go on and on just to illustrate that astrology has been tested for a scientific basis of predictivity in numerous ways by numerous research workers on numerous occasions—and has always been found wanting.

Individually or as part of a larger group man has always lived by certain traditional beliefs. These beliefs are inextricably mixed with his cultural and religious heritage. Inevitably conflicts arise whenever the critical appraisal inherent in the scientific temper is applied to these beliefs.

Some conflicts arise because the beliefs or the rituals they imply had a rational basis in the olden days but which they no longer possess today. Some rituals had a symbolic meaning in the social ambience of several centuries ago; today they have become irrelevant. The question arises: what should one do in case such a conflict arises?

This issue has become more urgent in view of what Alvin Toffler calls the 'Future Shock'. The

rapid inputs from science and technology in the last century—more so in the last few decades—have had severe repercussions for human societies the world over. How to adjust to the rapid growth of knowledge, to the many ways energy can be used to upgrade human existence, to the many effective ways one may destroy human existence, to the severe impact of all this on our natural habitat...? These are questions which perhaps could have been handled had the societies been granted the luxury of ample time. This, unfortunately, is not the case. The response has to be quick to a rapidly changing scenario. How to absorb the 'new' while holding on to the 'traditional'?

On the 'traditional' side we have the traditional virtues of the individual's responsibility to the society, the society's commitment to ensure the well-being of its members and the individual and social commitment to preserve the natural habitat around us. Armed with these virtues man can assess what science has to offer: he can take judicious decisions on what to accept and what to reject. This is where the scientific temper comes to his help.

The technologically advanced nations of the West have been experiencing the ill effects of uncontrolled impact of science and technology on the society. The destructive nuclear arsenal, the excessive industrial pollution, the enforced idleness and consequent psychological problems of mechanisation, etc. are there to see. Does this mean that we must put a stop to all scientific and technological development?

Such a response, already advocated by a few in the developing nations, indicates a panic reaction. Given the traditional virtues mentioned above as guiding principles it should be possible to take a rational path that skirts around the above pitfalls.

Miracles of Science Benefit All

Indeed, at first sight these problems before us appear to be formidable if not insurmountable. 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. The achievements of space technology with such highlights as the manned trips to the Moon, the landing on Mars and the SITE programme in our country, the rapid growth of communications which has

dramatically brought the far corners near, the advances in medicine, biology, agriculture—are they not scientific miracles happening before our own eyes and achieved during less than the span of a generation? Unlike the so-called miracles of the so-called godmen, *the miracles of science benefit not one single individual, but a whole class of humanity*. They benefit the poor as well as the rich. The invention of electric power not only runs the gadgets of the rich, it also provides light to the remote villages.

The developed nations have recognised these facts and they not only support science in general but also continue to encourage basic research, which at first may appear 'useless' but may lead to useful applications like those just mentioned. For us to ignore basic research at this stage would mean that we will have to keep on importing new ideas from abroad. This would be contrary to our policy of self-reliance. India has plenty of talent for basic research, most of which is untapped. Suitable support for basic research will unearth this talent and bring in its own rewards in the long term if not immediately. Right now I can think of one analogy to illustrate my point of view. 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 forever be dependent on oil imported from abroad. And, finally let me emphasise that basic research does not require heavy financial outlay. We must, however, ensure

with adequate safeguards that the research produced is of first class quality.

When Lord Krishna finished telling the *Gita* to Arjuna, he ended by saying:

Vimrsyai'tad as'esena

yathe' c'hasi.tatha kuru

(Reflect over what I have said fully and then do what you wish.)

In a sense this is what the scientific temper calls upon us to do: to weigh in all the evidence and then decide what is best.

As has happened in science, occasional 'wrong turnings' with false ideas have caused deviations from the path of progress; so such attempts to decide what is best, may occasionally lead to wrong decisions. But, the self-correcting tendency of science will operate here too, telling us that we have taken the wrong turning and we need to go back and rectify the mistake. The scientific temper guides us towards recognising this eventuality and to allow for mid-course corrections. I am confident that if, and only if, we are not blinded by traditions and dazzled by science but keep our visors open and our minds alert our country will make a triumphant entry into the twentyfirst century. ■

(Courtesy: *Man and Development*, March 1993)

References

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