The Scientific Temper: Indispensable to Enlightened Citizenship

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Introduction

It is often stated that we live in the age of science, that science and technology are shaping our very existence. No one described the impact of science and technology (S&T) more graphically than Alvin Toffler in his book *Future Shock*. I summarize in my own words his description of the way science and technology have come increasingly to determine the conditions under which we live and why this circumstance has come like something of a shock to human societies the world over.

Let us do some elementary arithmetic! Divide the last 50,000 years or so of known human existence on this planet into some 800 human lifespans each lifespan comprising 62.5 years. Take this typical human lifespan as a representative unit of time. Of these 800 time units, for which some historical information is available, the first 650 or so were spent by man living in primitive conditions. The art of writing is not more than 70 lifespans old and that of printing is only 6 lifespans old. The electric motor is 2 lifespans old. In fact, most of the things we use in our daily existence involve technology much younger, some of it not more than 1 lifespan old. The discovery of atomic energy, the use of space technology and the proliferation of computers are all less than a lifespan old.

This indicates how rapidly scientific ideas are being translated into technological inventions and how rapidly we are having to assimilate them in our lives. Yet this speed is not proving entirely beneficial to society. Rather, the situation resembles that of a person at a buffet dinner confronted with a feast of excellent dishes served in rapid succession. The banquet may look dazzling but the diner ought to pick and choose keeping in mind the limitations of health and digestive capacity. This human society has not yet learnt to do.

The diner in the above example may ask: 'How do I know what is good for me, and how much, and what items should I avoid?' Who is to tell him? For the twenty-first-century citizen, this need for advice can be satisfied by a proper society-science interaction. Science communication in various forms can help inform the citizen about what is happening in S&T, while the development of the scientific temper can help shape the individual's attitude towards this information. In fact, as I will argue later in this article, the scientific temper is essential to the well-being of both society and the individual.

Science Communication

Information holds the key to facing the future shock. Whenever new discoveries in technology take place, it is necessary to understand their full implications. Very often a technology is announced but the science it is based on is not so well publicized. Even leaders in the field sometimes fail to grasp the potential of a discovery. There are famous examples. Thomas Alva Edison, the great inventor, did not believe that alternating currents would play any useful role. Lord Rutherford, who discovered that the composition of an atomic nucleus can be probed and transmuted, did not believe that the discovery had a practical implication. Within three decades, the discovery was put to a highly destructive use—a nuclear holocaust—as well as to peaceful use in an atomic reactor for generating energy. After the early rocket experiments many distinguished scientists believed that space technology would play no important role.

Examples like these suggest that there needs to be a lot of public discussion between scientists, leaders, and decision-makers in society whenever any new scientific discovery is made or is in the offing. What are the future implications of the discovery? Is it likely to be harmful to society? Does it need to be channelled in a certain direction? In the physical sciences, nuclear studies have already shown us, perhaps too late, why one needs to exercise control on the direction of research. The technique that enables one to know the sex of the child before it is born had to be restricted because of its misuse. Evidently, these are situations wherein scientists have to come down from their labs and studies to talk practical matters with society.

Science communication is therefore extremely important—much more important than appreciated by the common man. Not only do scientists need to come out and communicate, there can be a whole class of communicators who are basically good at communication, who read scientific literature or consult with the experts and then tell the others what they learn. Today it is possible to use different media for science communication—the radio, TV, the Internet, lectures, movies. A number of voluntary organizations have come up to pursue this objective, but much more needs to be done.

India has a number of such organizations, national as well as in states and towns. The Government of India has supported such activities through Vigyan Prasar, which is under the Department of Science and Technology. Then there is the National Centre for Science Communicators, headquartered in Mumbai, which played a very active role in the nucleation of the International Union of Science Communicators (IUSC). I am happy to say that the IUSC was recently established with headquarters in Mumbai.

Science Journalism

An important arm of science communication is science journalism. It is sadly much neglected in India. Reporting of scientific events is allotted only a very small percentage of newspaper space. Very often a science news item is simply taken over from foreign sources 'by arrangement'. Clearly, science is not a priority in the minds of newspaper producers or editors.

Investigative journalism these days covers many cases of corruption, crime, spying, conspiracy and war stories. Once in a while, the scientific world too offers challenging and highly interesting cases. In a typical case, a claim to an important discovery is made but without proper substantiation. In some situations the result is based on fraud while in others it is a genuine mistake. There are also instances of scientific plagiarism. So it is not a case of 'no news is good news'. Perhaps journalists could at least cover these examples of malpractice in science! I may give a classic example from the past.

In 1903 the eminent French physicist R Blondlot claimed to have discovered a new type of radiation called N-rays (*N* for the town of Nancy, where the discovery was supposedly made). Coming shortly after the discovery of X-rays in Germany, this discovery of new rays with remarkable properties was hailed widely in France, partly because of the rivalry between the two neighbouring countries in many fields including science. N-rays became fashionable and a large number of research papers on them began to appear in French journals. Soon Blondlot was awarded the prestigious Lalande Prize by the French Academy for this discovery.

However, a scientific experiment is nothing if it is not repeatable. This was not happening in the case of N-rays. The rays could not be detected in similar experiments in England or Germany. What was wrong? In order to find out, British scientists requested R W Wood, a distinguished American scientist, to visit Blondlot's laboratory and inspect the experiment. (A scientist from a rival country like Britain or Germany would not have been welcome in France!) Wood made the trip and found that the claim for N-rays was totally false. His own account of how he detected this fraud makes a

very interesting reading even for the layman.

The temptation to make spectacular but fraudulent claims is stronger nowadays than it was a hundred years ago, when times were relatively placid. This is because a scientist is judged by his performance much more stringently today than he used to be in the last century. Awards, peer support, promotions, and project grants are all linked with performance. Thus, if Mr X has made an extraordinary discovery he stands to attract a lot of financial support as well as wield much power in scientific circles. So there is a strong temptation for him to rush out and make premature announcements. In spite of these temptations, science has remained relatively clean mainly because a scientific fraud is detected sooner than later. However, such cases as do turn up from time to time need to be widely reported to the public.

Another related area where investigative journalism can do a lot is in testing the claims of UFOs as extra-terrestrial spacecrafts. The so-called unidentified flying objects are reported in the press from time to time. The common man gets excited by the suggestion that these are spaceships from some alien civilizations beyond our Earth. The real explanations could be quite mundane: the object may be Venus, or an optical illusion (like a mirage), or a man-made spy satellite, or simply the figment of a highly fertile imagination.

Philip Klass, a Washington DC journalist, has written a book entitled *UFOs Explained*, in which he has given absorbing details of investigative journalism which removed the mystery around several such claims. He has also shown how the so-called photographic evidence can be faked. Indeed, in some cases the UFO sighting has been fraudulently turned to material gains.

Another set of events which generated considerable excitement around twenty-five years ago related to the apparently strange events occurring in the so-called Bermuda Triangle. These were debunked by science journalism, although in India they still exist in the popular imagination.

The Scientific Temper

A few years ago I attended an international inter-disciplinary conference dealing with some issues man will have to face in the twenty-first century. Naturally, topics such as global environment, population control, food availability, communications, education, and science and technology featured prominently. As speaker after speaker covered a variety of subjects of great relevance to the main theme of the conference, I increasingly began to feel like a diner at a sumptuous meal searching desperately for that tiny but vital item, the salt shaker. That pinch of salt is the scientific temper, which is such an essential component of man's mental framework in his struggles to face the challenges of the present and the future.

What is meant by the 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, civilizations? 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 very effectively by Pandit Jawaharlal Nehru in his *Discovery of India*:

> 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.[1]

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 Nehru considered so essential for our future well-being. To understand what the scientific outlook is all about, let us first see how science itself works.

There are three steps in the progressive march of science: experiment and observation, theoretical interpretation, and prediction of

new results. This sequence is endless. One performs an experiment in the laboratory or observes some natural phenomenon and then tries to interpret it in terms of a theoretical framework. If the attempt succeeds, then one tries to make new predictions that future experiments or observations will verify. If the success of the theory continues, one keeps believing in the theory. *However, one must never think that the theory will hold good forever.* There is always a possibility that a future experiment will disagree with the present predictions of the theory, in which case it may have to be abandoned or modified or replaced by a new and better theoretical framework. Thus, Newton's law of gravitation continued successfully until some sophisticated tests in the solar system showed its inadequacies and it was replaced by Einstein's theory of relativity. 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 mechanizing 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 co-operation, it depends on people testing each other's work and it depends on people taking notice of each other.[2]

Bondi's comment needs one clarification. It does not mean that any Tom, Dick or Harry can propose 'new ideas', claiming to be better than Newton or Einstein. I get such ideas from dozens of people—vague flights of imagination with no backing of quantitative facts—in the post . Bondi here means ideas carefully worked out with rigorous mathematics and having the benefit of confirmation by physical facts. In fact there is no simple way to truth, whatever it may be. One needs patience in putting together whatever understanding of nature our society has acquired and build on it towards a greater understanding.

The scientific outlook has evolved from this practice of science: it relies on factual evidence and statements that can be checked against established truth. It allows for pragmatism, that is, the willingness to drop a paradigm if it fails the test of facts and adopt a better one if it meets all factual checks. 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, can be scientific. Indeed, just as progress in science could be achieved only when the scientific outlook prevailed over innate conservatism, so in human society this outlook acts as an antidote to the evils of prejudice and superstition.

Science and Superstition

Superstitions are born out of ignorance of how nature functions. Science is dedicated to the unravelling of the mysteries of nature. When a 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 occult powers to planets. This assumption arose from ignorance of what planets are and how they move. Now that astronomy has answered all of the questions raised about planets by the primitive man, we should expect this assumption to be regarded as groundless. But this has not happened. Even in technologically advanced countries this belief persists among sections of the educated classes. In the mid-1970s a group of leading scientists including several Nobel laureates in the West signed 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 positions 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 realize that our futures lie in ourselves, and not in the stars.[3]

Do planets influence human destiny? The subject of astrology is based on a positive answer to this question. But how will a scientist go about testing the hypothesis that the answer is yes? He will not be satisfied with a single person's prediction 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. Then 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 such trials under different conditions. Further, it is necessary to cast the prediction in a well-focused form that can be tested. Such tests as have been conducted so far by scientists have yielded negative results. But again, it is not always necessary to call upon a professional scientist to perform such tests. The educated common man can himself sift through the evidence provided he adopts an objective outlook. Let me give one illustrative example.

A comprehensive test was conducted by Bernie Silverman, who sampled the marriage and divorce rates in Michigan in 1967 and 1968. His sample was large: 2,978 marriages and 478 divorces. The birth charts of the couples involved were examined by astrologers, who were asked to opine on whether the horoscopes matched sufficiently to warrant the conclusion that their marriages 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; those in the former category would have a stable and happy marriage whereas those in the latter would not. These 'predictions' were then compared with the actual state of marriages of these couples, some of whom, as stated earlier, were happily married while others had divorces or broken marriages. It was then a simple matter to test the argument against the actual and predicted classifications of the samples. Rigorous statistical analyses demonstrated that there was no correlation between the predictions and the actual results.

I could go on with other examples to illustrate that astrology has been tested for the scientific criterion of predictability in numerous ways by numerous researchers 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 faculty inherent in the scientific temper is applied to those beliefs. Some conflicts arise because the beliefs or the rituals such beliefs are associated with had a rational basis in the olden days but which they no longer possess today. Some rituals may have had a symbolic or even a practical meaning in the social ambience of several centuries ago, but today they have become irrelevant. So what is one to do when such conflicts arise?

'Tradition' upholds values such as the individual's commitment to society, society's responsibility for the well-being of its members, and the joint duty of the individual and society to preserve the surrounding environment. Armed with these values man can assess what science has to offer; he can make judicious decisions as to what to accept and what to reject. This is where the scientific temper comes to the help of society as a whole.

The technologically advanced nations of

the West have been experiencing the ill effects of the uncontrolled impact of science and technology on society. Destructive nuclear arsenals, excessive industrial pollution, enforced idleness brought about by automation, and the consequent psychological problems of mechanization are there for all 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. With the traditional virtues mentioned above as guiding principles it should be possible to follow a rational path that skirts round the pitfalls.

The Present Status

Let me review briefly how we Indians stand today vis-a-vis Nehru's remark that 'only when we are politically and economically free will the mind function normally and critically'. A dispassionate survey presents a mixed picture.

As I mentioned earlier, we have several NGOs devoting their efforts to spreading rationalism and eradicating superstitions. There are organizations which conduct public awareness programmes through lectures, demonstrations, street plays, experiments debunking miracles, articles and books on the importance of the scientific temper, and so on. The National Council for Science and Technology Communication (NCSTC) in New Delhi has been supporting such programmes in an imaginative fashion. The NCSTC was responsible for making 28 February the National Science Day, in commemoration of C V Raman's discovery on that date in 1928 which fetched him the Nobel Prize in physics. On this day (and throughout the week covering this date) several public awareness programmes are conducted across the country and scientific institutions keep open house with audio-visuals on their work, exhibitions, lectures, etc. Some institutions organize special quiz programmes and competitions for schoolchildren.

While several such governmental and non-governmental efforts are going on in an organized manner, what is the mindset of the man in the street? Can we confidently assert that in the half century since independence we have made a significant dent in the wall of superstitions that have steadily thickened over the centuries? We may remember, for example, the great social reformer Raja Ram Mohan Roy and his crusade against the practice of sati. But there still take place isolated incidents of this practice, and they attract crowds of believers.

Nor is superstition confined to villages. Not a long time ago, the episode of idols of Lord Ganesha drinking milk drew large crowds in Delhi, Mumbai and other cities with even some ministers expressing their wonder and joy at the sight. It did not take long to debunk the phenomenon in terms of known science, but the spontaneity of belief was a give-away that betrayed the fact that the veneer of science and technology on society was indeed very thin.

But perhaps of greater concern is the *rising trend* towards superstitions. Several symptoms of this trend can be cited:

- More marriages are being decided by the matching of horoscopes than were done a generation ago. I know of parents whose marriages did not pass through the 'horoscope filter', but whose children feel it is a necessary criterion for their marriage.

Easier to match horoscopes than hearts!

- With new technology, new superstitions are getting hold of society. A recent rage is Vastushastra and its Chinese counterpart, Feng Shui. Influential politicians and leaders of soci-

ety have been swayed by these new cults though none of their claims have passed scientific scrutiny.

• Despite the scientific debunking of godmen's miracles, a large section of even educated urbanites continues to believe in 'babas' who demonstrate their superhuman powers through miracles. This is an area on which science journalism could bring its investigative skills to bear. So far it has registered moderate success, but much more needs to be done.

• The legitimization of astrology as a science by the University Grants Commission is another symptom of this unfortunate trend. The UGC uses the term 'Vedic astrology', implying that the subject is of Vedic origin. All historical evidence, however, shows that planetary astrology using horoscopes came from the West—from Greece, Babylon, and such places.

Miracles of Science Benefit All

One could easily enlarge the above list. Granted that there are problems with excessive reliance on automation, environmental hazards with indiscriminate use of technology, and serious dangers to society from continuing certain areas of scientific research. But this does not mean that we turn away from the scientific path and go back to age-old superstitions which have been proved invalid.

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 manned trips to Moon, landing on Mars and the Satellite Instructional Television Experiment (SITE) programme in our country, the rapid growth of communications which has dramatically brought far corners near, the advances in medicine, biology, agriculture—are they not scientific miracles happening before our own eyes and achieved during a time span of less than a generation? Unlike the so-called miracles of so-called godmen, *the miracles of science benefit not one single individual, but the whole of humanity.* They benefit the poor as well as the rich. The invention of electric power not only runs the gadgets of the rich in cities, it also provides light to the poor in remote villages.

The developed nations have recognized 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 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. I will use an analogy to illustrate my point. Imagine a country which has vast untapped resources of oil, but will not search for these for reasons of heavy financial outlay. Such a country will forever be dependent on imported oil. And finally, let me emphasize that basic research does not require heavy financial outlay when compared to its rich potential. We must, however, ensure with adequate safeguards that the research produced is of first-class quality.

Near the end of His exposition of the Gita, Sri Krishna says to Arjuna, 'Having reflected on what I have said fully do as you wish.' In a sense this is what the scientific temper calls upon us to do: to weigh all the evidence and then decide what is best. I am confident that if—and only if—we are not blinded by tradition or dazzled by science but keep our vision open and our minds alert, our country will make a triumphant march towards progress in this century. *

References

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