Values in Science and Technology

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The word 'science' is derived from the Latin *scientia* meaning 'knowledge'. It thus represents the entire content of human knowledge. However, popular usage restricts it to the well-established natural sciences, viz., physical, chemical and biological sciences. Occasionally, mathematics is also included in this definition. It excludes all forms of knowledge which are intuitive in character and which cannot be explained by general laws.

Human knowledge about nature has been reached through a painstaking process of inquiry and discovery and innumerable errors. According to some diehard admirers of science, the acquisition and systematization of such knowledge is the only human activity that is truly cumulative and progressive. This point of view is not, of course, accepted universally. It is true that the triumphs of science represent a cumulative process of increasing knowledge and a sequence of victories over ignorance and superstition. It is also true that a stream of inventions has flowed from science for the improvement of human life. Nevertheless, there is now a better realization of deep moral problems within science, of external forces and constraints in its development, and of dangers in uncontrolled technological change. This has naturally led, in recent years, to a reappraisal of the value system governing science and technology, leading to a critical reassessment of their role in human life.

Value Systems in Science and Technology

The word 'value' is freely used in several contexts, but its meaning is somewhat vague. The dictionary meaning is 'that which is worthy of esteem for its own sake.' Books on moral philosophy define it as 'a belief that a specific mode of conduct or objective is personally or socially desirable.' According to St. Augustine, value is based on the will of God. Kant believes it to be based on reason aided by categorical imperatives. Hume feels that value judgments are based on human nature, sympathy or selfishness. Jeremy Bentham is of the opinion that it is based on the calculation of the greatest happiness of the greatest number. Even though these definitions differ from one another, there is a general common sense view that human values are a mixture of emotion, self-interest, reason, religious belief, and the experience of people in human society.

There is a mistaken impression among the nonscientific community that science is not concerned with values. But most people who are actively engaged in scientific research feel differently. Their experience is that scientific research is best done by a commu-

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nity which respects certain values. In his classic study of the sociology of science, Robert Merton enunciates four principal values, viz., universalism, communalism, disinterestedness, and organized scepticism.[1] These values are respected by scientists, not because they are personally more virtuous than non-scientists, but because if they do not obey them, their work will not be accepted and valued by the scientific community.

UNIVERSALISM. Universalism requires that science should be independent of race, colour or creed, and that it should be essentially international. In this sense, science is indeed a unifying factor among diverse races and creeds. It is rather unfortunate that the same cannot be said of religion and its practice. There is a specific reason for this. Any Tom, Dick and Harry who knows how to read and write can set himself up as an authority on religion. Most of the global conflicts based on religion can be traced to this cause. However, this is not possible in science. No scientist who claims to practise his profession can transgress this value of universalism, because he simply will not be acceptable to the community. There are no 'false prophets' in science.

Einstein is well-known as the discoverer of the Theory of Relativity. He enunciated the Special Theory in 1905 and followed it up with the General Theory in 1916. The latter was confirmed by Sir Arthur Eddington in 1919 through his famous observations of the deflection of star-light by the gravitational field of the sun. Einstein became a celebrity overnight and was acknowledged all over the world as the true successor to Newton. However, this was the time when anti-Semitism was on the rise in Germany and Einstein was a Jew by birth. With the rise of Adolf Hitler to power, Einstein had to flee Germany to England, and later to USA. So much was the hatred of Hitler towards Jews that he dubbed the Relativity Theory as 'Jewish Science' and banned its teaching. He was supported in this mad venture by Phillip Lenard, who was himself a Nobel Prize winner in physics. This is one of the most sordid chapters in the history of twentieth century science. But this tirade of Hitler and Lenard could not find general acceptance with the scientific community, because of its deep-rooted commitment to the value of universalism.

COMMUNALISM. Communalism requires that scientific knowledge should be public knowledge. It also implies freedom of exchange of scientific information between scientists everywhere. It demands that scientists should be responsible to the scientific community for the trustworthiness of their published work.

The concept that the results of scientific research should be published for public knowledge started in Europe with the establishment of scientific academies like the Royal Society of London and the French Academy of Sciences in Paris. Since that time, it has become a tradition for all scientists to publish the results of their research in journals, whose numbers have now proliferated. The publication of any research work is not automatic. The paper communicated to a journal undergoes a rigorous peer review and is accepted for publication only when it satisfies the last requirement of communalism, i.e., the published work be trustworthy.

The Principia Mathematica, Newton's greatest achievement, was published in the year 1686. This contains the famous result about the application of his gravitational theory to the calculation of moon's orbit round the earth. Newton had completed this work almost twenty years earlier. Unfortunately, his calculations did not fully tally with

1. Merton, R. K., *The Sociology of Science* (Chicago University Press, 1973).

available astronomical observations. Newton thought his theory was wrong and did not publish it. A crucial information needed for this calculation was the distance of the moon from the earth. He had used the value of this parameter based on the available records in the 1660s. More careful observations a couple of decades later showed that the earlier data was wrong. The more accurate value of moon's distance from the earth then became available to Newton. When he used this new value in his equation, he found a perfect agreement between his calculations and the observations. He then decided to incorporate his gravitational theory in the *Principia*. This is a typical illustration of the fidelity needed in scientific research.

Freedom of exchange of information between scientists is a sine qua non for the growth of science. That such an exchange is possible even in the midst of war is dramatically proved by the verification of Einstein's General Theory of Relativity. The epoch-making paper by Einstein was published in Germany in a German journal in the year 1916. Within a few months this came to the attention of Arthur Eddington in Cambridge, who started raising funds for an expedition to South America to verify the theory at the time of the solar eclipse predicted for 1919. This was the time when the First World War was at its most intense phase. Today, in retrospect, Eddington's project appears to have been foolhardy, but to Eddington, a true scientist, the war was irrelevant. For him the more important thing was Einstein's work. The verification of the General Theory by Eddington in 1919 firmly established its trustworthiness, leading to a revolutionary change in our concepts about the Universe.

Disinterestedness. This value requires that the results of bona fide scientific research should not be coloured or manipulated to serve considerations such as personal profit, ideology or expediency. In other words, they should be honest and objective. It is the impersonal nature of science which is its greatest strength.

The best example to show how science can get distorted if it is manipulated to suit an ideology is Soviet science during the communist regime. In its desire to prove the superiority of Communism over Capitalism, the Soviet regime forced the scientific community to claim that most of the important scientific advances made by the West had already been done in USSR much earlier. It was even claimed that the Theory of Relativity and Quantum Mechanics, which revolutionized human thought in this century, had already been discovered by Soviet scientists long before Einstein and Planck. The international community, however, could not swallow such a claim, because there was no proof available.

Many times it may so happen that different groups around the world may be working on the same research problem simultaneously. In such a situation, there often arises the question as to which group came up with the solution first. To resolve such conflicts, the scientific community has evolved a very efficient system. As soon as the results of a research work are communicated to a journal, the date of communication is registered. The paper is then sent to a set of referees, whose comments are essential to decide the quality of the work. If the paper is unconditionally accepted, it is published in the journal, indicating clearly the date on which it had been first communicated. In the event of the same results being published by different authors or different groups of authors, the date of communication is taken to establish priority. When C. V. Raman made his famous discovery leading to the Raman Effect in February 1928, he immediately wrote it up as a pamphlet, got it printed and rushed copies to all well-known scientists around the world. There were two more groups working on the same problem, one in France led by Cabannes, and the other in Russia led by Landsberg and Mandelstam. Since Raman publicized his results first, he was given the credit for the discovery and was awarded the Nobel Prize.

Plagiarism, or one scientist appropriating the work done by another scientist, is not uncommon in science But because of free communication, the unwritten code of checks and balances is so effective that people just cannot afford to get away with plagiarism. This is one of the greatest strengths of science, that fraud gets detected easily and early, and also gets well publicized.

ORGANIZED SCEPTICISM. This value requires that statements should not be accepted on the word of authority, but that scientists should be free to question them and that the truth of any statement should finally rest on a comparison with observed fact.

The most dramatic illustration of this is the case of S. Chandrasekhar, Indian-born Nobel Prize winner, who passed away recently. He is famous for his work on the behaviour of stars whose mass is greater than 1.4 times that of the sun. This is named after him as the Chandrasekhar Limit. He discovered his results when he was working in Cambridge, in 1930s, and showed them to Arthur Eddington, who had already earned world renown for his solar eclipse expedition to verify Einstein's General Theory of Relativity. Eddington was not convinced of Chandra's work and is reported to have said, 'Oh yes, your mathematics may be all right, but I don't think your physics is correct.'

Chandra decided to present his results in January 1935 at a meeting of the Royal Astronomical Society in London. According to the programme, Eddington was supposed to speak after Chandra. Chandra duly presented his results and was confident that the audience would appreciate his work. But to his horror Eddington, who followed him, ridiculed his work and cracked several jokes at his expense. Chandra was just a young Indian student and had no one to support him. He was deeply disappointed and left Cambridge once and for all for Chicago. Later observations and calculations, however, have vindicated Chandra and the scientific community honoured him profusely. But what is important to note is that even a great scientist like Eddington could not help his personal preferences intruding into his perception of work done by others.

After his epoch-making research in Relativity and Quantum Theory, Einstein became convinced that there exists a Grand Unified Theory which explains the whole universe. However, he was dismayed to note Schrodinger and Heisenberg introducing probabilistic concepts into Quantum Theory and made the famous statement: 'God does not play dice with the universe.' In spite of Einstein's objections and scepticism, it was the theory of Schrodinger and Heisenberg, who were still young novices, which gained acceptance, because they predicted and explained many new phenomena.

Innumerable are such instances in the history of science, where ideas have been accepted by the scientific community impartially, whether they came from a famous scientist or a novice. One of the greatest dangers faced by any society is credulousness and the antidote to this is a passion for the truth of fact. It is a precious yet vulnerable quality of the human spirit and science is its guardian.

Impact of Technology on the Value System

If we ask the man or the woman in the street what they think of science, what would their response be? About three centuries ago, at the time of Newton, most of them would have been unaware of what science is, except for a few who would have considered it as a pastime for the rich. About a hundred and fifty years ago, they would have acknowledged that science has made their lives more comfortable. They would have looked up to science to improve their material standard of living.

Today the answer would be completely different. The growth of science and its application to practical life in the form of technology have been so breathtakingly rapid in the current century that there is a sense of disquiet. Most people would regard science today as a mixed blessing. While there is a general feeling that science is a noble undertaking and necessary for the expansion of human knowledge, the same may not be said of technology.

Let us take another look at the values in science, enunciated in the earlier section, and see how they are viewed by technology. The value of universalism demands that knowledge be truly international. This is not true of technology. Today, thanks to the commercial exploitation of science and the related Intellectual Property Rights, technology has become the property of individuals or corporations. Consequently, it is no longer part of public knowledge, which is the basis of communalism. With the growth of Military Science and Defence Research, many technological developments have become classified and closed to the international community. This was particularly the situation during the era of the Cold War, when industrial and military espionage was at its highest. It was the personal experience of many of us in international conferences to meet Soviet scientists who could speak excellent English, but were accompanied by 'interpreters'!

Scientific research is no longer free of ideology, as witnessed, again, during the Cold War. The Russians launched the Sputnik and claimed that their science and technology was far superior to that of the Americans. Not to be left behind, the Americans landed a man on the moon claiming the supremacy of American science and technology. Even countries which cannot afford to provide food, clothing and shelter to their citizens are in a race to procure or develop bombs and missiles, because it is a matter of prestige for them to do so. The victim in this process is, of course, the value system on which science is based.

What about the cultural dimension of science? There is a general feeling among the public that science has dehumanized our view of the world. It is said that scientific thinking is 'mechanical' and not 'human' and has diverted the minds of people from spirituality and humanism. In the words of Sri Aurobindo, 'Even the discoveries of physical science have been elevated into a creed and in its name religion and spirituality banned as ignorance and superstition, philosophy as frippery and moonshine.'[2] Such accusations against science are not new. Even Newton feared that too wide an application of sciences would disenchant the world by reducing the need for God. The effect of such objections and accusations has been to make the public less friendly to science, to weaken the ideal of science as a vocation, and to put science on the defensive.

Are these criticisms justified? Part of the problem is that people often confuse science with technology. It is technology, emphasizing the material aspects of science, which is responsible for the concern expressed by thinkers like Sri Aurobindo. It is true that

2. Sri Aurobindo, *Essays on the Gita* (Pondicherry. Sri Aurobindo Ashram, 1989).

science and technology are distinct from each other, but it is hard to make that distinction in practice. There is a joke that if some major venture succeeds, it is called a 'triumph of science,' but if it fails, it is called 'failure of technology'!

Value-based Science Education

Can something be done to remedy the situation? If it is a fact that most of the modern-day problems like pollution, global warming, ecological disasters, etc., have been due to the application of science, the remedy does not lie in discarding science altogether. The hope lies in solving these problems with the proper application of science. If the hole in the ozone-layer is caused by chlorofluorocarbons emitted by refrigerators and airconditioners, the solution does not lie in shutting down all such facilities, but in finding a substitute which is harmless.

To get more of what is desirable and less of what is undesirable, we must learn to control the applications of science embodied in new technologies. Many of the problems we are facing today—like nuclear waste disposal, toxic chemicals, misuse of genetic engineering, the import of new, unfamiliar and dangerous technologies by developing countries—are too complex to be tackled by passing legislative laws. If science and technology have created these problems, the two should be harnessed to provide solutions also.

It is here that education plays an important role. I am not referring here to school or college curriculum alone. We need to educate the public, the policy-makers, the bureaucrats, and even scientists, on the implications of new technologies. An open public debate many times brings greater cooperation from the various sections of society. The best example is the hazards of nuclear power. So long as the public is not properly educated about the pros and cons of nuclear power, there will always be a feeling of suspicion and fear. We are always more afraid of unknown dangers than known perils, the reason why we see ghosts in the dark and not in broad daylight. It is here that scientists have to play their part in demystifying science and bringing it with all its glory and faults to the man and the woman in the street.

The teaching of science in our schools and universities hardly achieves this purpose. According to John Ziman, '...the place of science in the popular culture of our time and the role of the scientist in contemporary society are largely determined by the way science is taught in the classroom. Although most people learn very little science, and make very little use of what they learn, they are the silent majority whose views eventually carry more weight than the tiny minority of research workers and advanced technologists. They too must learn something about science as part of their education about things in general.'[3] Of course, we cannot expect every 'educated' person to know much of actual, hard science as practised by scientists. But it is desirable that every 'educated' person should know more *about* science.

The key to a peaceful and happy existence on this mysterious planet is a better understanding of ourselves and the world around us. We know more about ourselves and the world than any society has ever known before, thanks to modern science. If we have to use this knowledge wisely, we need to treat science as an integral and valuable part of our culture and not simply as an agent of material progress. We need to respect and cherish the value system that has made science such a thrilling adventure.

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3. Ziman, John, *Teaching and Learning about Science and Society* (Cambridge University Press, 1980).