

Science & Technology - Whither and Wherefore ?

B.V. Sreekantan
National Institute of Advanced Studies, Bangalore

The venerable American President Abraham Lincoln once said "If we know where we are, where we are going, we can better understand what we must do." This is perhaps the best advice for any one who is on the threshold of choosing a career, be it in the field of science, technology, business or any other vocation. In this article, I will place some thoughts on science and technology which may be of use for any youngster who would like to pursue a career in science, be it from the point of view of striving for academic distinctions or from the point of view of entering a field surfeit with job opportunities of every kind that one is looking for.

Science, which branched off from philosophy about four hundred years ago has the same objective, namely the quest for knowledge and understanding of the variety of phenomena in the animate and inanimate world that man experiences. The methodology of science however is distinctly different from that of philosophy. The emphasis in science is on observation / experimentation, postulation of a theory based on concepts developed in the first instance on everyday experience, mathematical formulation wherever necessary and possible, prediction of newer phenomena and further experimental verification. In science experiment is the

final court of appeal. There have been many instances when a beautiful theory has been thrown out on the basis of just one ugly fact of observation.

Science based technologies:

Historically, long before the advent of science, man driven by the compulsions and necessities of 'living' - food, water, shelter, protection from wild life, natural disasters etc., had developed over the centuries a variety of tools and also had evolved certain practices. With the advent of science the tools got refined and became more effective and the practices rendered rational. New science based technologies transformed life styles. Large cities - the megapolis came into existence with multi-storeyed buildings, network of roads, centralised water and electric supply, street lighting, sewage systems, telephones, telegraphs, postal systems, new modes of transportation - all of which had base in technological developments. Along with these 'goodies' of technology also came the serious problems of pollution of atmosphere and water, noise pollution, road and railway and aviation accidents, spread of communicable diseases, etc - the solution of which required more science and more technology. Associated global problems of deforestation, depletion of natural resources, changes in climatic conditions, increasing defence requirements focussed attention on development of more and more sophisticated technologies. In a sense man became a slave of technology.

Those countries which have advanced technologies have gained a natural advantage.

It is important to recognise that all the sophisticated technologies in the service of man to-day have emerged out of discoveries made in the field of basic or pure sciences that were pursued with the dictum: "Knowledge for the sake of Knowledge", without any applications in mind. A few examples may drive home this point. The entire field of electrical power generation, which is the heart of modern civilization, was the result of the discovery of the laws of magnetic induction by Faraday. It is said that when Gladstone queried about the practical utility of his discovery, Faraday replied "you will one day tax it."

The theoretical discovery of the Electro-Magnetic Waves by Maxwell (based on Faraday's ideas of lines of force) and the subsequent production of radio waves by Hertz laid the foundation for the entire field of modern communication. Yet another glowing example of a fundamental discovery that had unimagined industrial consequences is the discovery of the 'electron,' by J.J. Thomson, followed by the discovery of the vacuum diode by Fleming and the Vacuum triode by de Forest. These launched the field of Electronics which got a boost of many orders of magnitude by the subsequent discoveries of the 'transistor' and its miniturised elaborations into large scale integrated circuits that ushered in the era of computers, and Space Technologies. Very few are aware that

the discovery of the transistor action had a lot to do with the developments in the abstruse and specialised field of quantum mechanics. It is also important to note that the early developments of computers and electronic instruments were motivated not by commercial considerations, but by requirements of the research laboratories working in the field of nuclear physics and elementary particle studies with accelerators. Strangely the founder of the IBM - the household name for computers to-day - T.J. Watson wrote in 1949 that although a single computer could solve all the scientific problems of the world, he did not believe that the computer had any commercial applications ! Such wrong perceptions about the future potentialities of scientific discoveries and developments are not uncommon even among top scientists. The discoverer of the nucleus and Nobel Prize Winner, Lord Rutherford observed in 1930 just before his death that any one who expects a source of power from the transformation of atoms is talking moon-shine !

Technology driven science:

It is not always that technology emerges from science. It has happened and continues to happen that new science emerges from technology as well. The most well known examples are the telescope and the microscope. The Telescope opened up the entire field of optical astronomy - revealed to us the stupendously vast universe populated with hundreds of billions of galaxies, each galaxy with hundreds of billions of stars like the Sun, and the entire universe continuously

expanding. The newer technologies have enabled observations in the Infratred, Ultraviolet, X-ray, γ -ray windows of the electromagnetic spectrum which have added new dimensions to our knowledge of the processes going on in the vast universe and have provided motivation for looking for extra-terrestrial intelligence. Einstein remarked that the most incomprehensible thing is that the universe is comprehensible, ofcourse to man.

The microscope opened up the mysterious microworld - revealed the happenings in the "cells" - the units of life - and to all the developments in the field of life sciences and also more importantly helped to track down the bacterial causes of deseases that made possible the wiping out of many of the dreaded infectious diseases and in recent years to all the beneficial aspects of genetic engineering. The accelerator technology opened the doors to the microworld of elementary particles and their interactions - provided the knowledge about the ultimate building blocks of all matter and radiation.

Interdependence of Sciences:

While most of the sciences developed independently of each other, in the recent decades there is closer interaction between the different disciplines and technologies developed in one area of science are finding almost immediate applications in other areas. This has naturally resulted in a faster growth of knowledge and consequent beneficial fall

outs. The medical science would not be what it is to-day without x-rays, Catscans, Tomographs, optical fibres, lasers all of which got developed in the laboratories of physical sciences. In fact biomedical instrumentation using all the newer developments in radiation detector technologies and electronics has become one of the exciting fields.

Serendepity - Chance discoveries

While in a general way it can be stated that scientific output is the result of long arduous hours spent by dedicated scientists in the laboratories or indulged in deep thinking finding theoretical understanding of observational results, it is to be pointed out that many an outstanding discovery that has even fetched Nobel Prizes is a pure chance discovery - which is given the name serendepity - distorted version of the Word Simhala Dweep (Ceylon) - two fishermen of Simhala Dweep went out fishing and by pure chance found new variety of fish that they had not been looking for or bargained for. The discovery of x-rays and the discovery of Radioactivity are themselves good examples of Serendepity. Neither Rontgen was looking for x-rays nor Becquerel for radioactivity. One was studying the phenomena associated with electrical discharges and the other fluorescence of certain chemicals. In more recent times the discovery of celestial x-ray sources which opened up the exciting field of x-ray astronomy and the discovery of Pulsars that led to the realisation that there is a new state of matter of very high density comprised of

only neutrons, kind of matter not encountered on earth, are fascinating examples. A rocket experiment had been designed to look for x-rays coming from the moon due to the impact of particles from the sun. It turned out that the most powerful source (Scorpins X-1) was in a direction close to the Moon on that eventful night just during these three minutes when the x-ray detectors were looking in the direction of the moon, and revealed itself. A graduate student working at the Cambridge University with Professor Anthony Hewish noticed while scanning through the chart records of the observations made with a radio telescope the occurrence of extremely regular sequence of radio pulses the kind of which had never been observed before. The follow up of this observation has led to the discovery of several hundred pulsars in the sky. An interesting question that has been raised in this connection is the following: If instead of a human being making the search, had a computer been programmed to scan, would the computer have recognised the unusual nature of the observation? The answer is obviously 'No' since it would not have been programmed to search for regular ^a pulses.

Planned Searches and Discoveries :

In contrast to these chance discoveries, there are also those which are made after careful planning, design and execution. The discovery of Radium by Madame Curie is one such. In more recent years the discovery of the fundamental particles called the intermediate vector bosons - W^{\pm} , Z^0

falls in this category. These particles with their characteristic properties had been predicted by theoretical physicists. But to experimentally establish these needed the construction of a new accelerator at CERN in Geneva costing millions of dollars and large teams of scientists and engineers had to work for several years to realise the objective. Such large scale enterprises apart from advancing the frontiers of fundamental knowledge, have many other industrial fall-outs.

One of the objectives of launching the large optical telescope on a Satellite, which is called the Hubble Telescope is to look for other planetary systems like the one we belong to - the Solar system. The evidence for existence of other planetary systems is extremely important from the point of view of searching for extra-terrestrial civilisations. There is no reason why in the vast universe, we should be alone.

The Future:

With all that is stated above, it may look that science and technology have advanced so much over the centuries that there is really very little that is left to be investigated by future generations, especially for those in the developing countries like India, which have yet to catch up a lot and which do not have the necessary infrastructure nor the resources. These are totally wrong ideas. In spite of all the advances in S&T, what we know is very little compared to

what we need to know about the workings of nature. Practically every field of science is crying for more knowledge and better instruments for carrying out deeper level experiments. A simple question like what is at the centre of the earth is not unambiguously answered yet. All these years the scientists were under the impression that the centre of the earth is filled with molten iron. Now based on some intricate observations they feel that the centre of the earth is a large single crystal of iron with specific orientation properties ! We still do not have the haziest idea even, of what it is that is exactly ~~is~~ responsible for the distinction between living and non-living matter, and at what stage the inanimate matter in its development becomes animate. Ofcourse there are still higher level questions like the relation between the brain, mind and consciousness. There are many diseases for which no cures have been found yet. We need new types of materials to be developed for the commercial exploitation of the most abundant supply of energy that is pouring down as solar radiation. We have not been able to simulate the fusion process that goes on the sun, in a way that can lead us to an exploitation of fusion energy. We have not solved the problem of metal fatigue which is responsible for most of the aviation accidents. One can go on listing any number of open ~~of~~ areas of research. ~~One can go on listing any number of open areas of research.~~ The facilities available within the country and the particular areas in which front ranking research can be done will become evident from the other articles in this special issue. What

is a pre-requisite is a proper appreciation of the potentialities of the field of science and technology and the intellectual challenges that they pose compared to other purely commercial fields of activity.