UNIT 34 SCIENCE, SCIENTIFIC METHOD AND PROMOTION OF SCIENTIFIC TEMPER

Structure

34.0 OBJECTIVES

This Unit on "Science, Scientific Method and The Promotion of Scientific Temper" is the last in this block. In the earlier units in this block, i.e., Units 31, 32 and 33 you had studied problems relating to the international environment to which our country has to react, and by which it is significantly affected. In this unit, you will study as to what makes for a scientific attitude (or `temper') on the basis of which we can objectively and scientifically examine the major problems of the world and how they affect our country.

- The objectives of this unit are:
- to acquaint you with the concepts of science, scientific method and temper
- to explain the possible attributes of scientific temper, and
- to briefly illustrate the benefits of science, scientific temper and scientific method to society.

34.1 INTRODUCTION

Article 51 A of our constitution which deals with fundamental duties makes it a duty of every citizen to develop a scientific temper. This is a good enough reason for young citizens to first

of all, find out what exactly is scientific temper, and then to try and cultivate it. But, even though it is important to carry out the duties laid down in the constitution, there are reasons other than formal and legal for understanding and practising scientific temper. If you have a scientific temper, you can understand and solve your problems with much less difficulty or stress, and you would be reasonable in your decisions and creative in your activities. However, scientific temper is no magical formula for success in life; nor can it be acquired suddenly by going through a lesson; it may, infact, take a life time of careful attention and examination of your own motivations and actions to acquire it.

Since a number of those reading this course would not be very familiar with science, we will first discuss - of course, very briefly - what is science? Even though we may not arrive at a clear cut definition of science, we should have some idea of the meaning and scope of this term. This will lead us to the second step of explaining what is called "scientific method" - and then, what may be called scientific temper. You will again find, perhaps to your surprise, that neither science nor scientific method are cut and dried simple terms possessing attributes which we can enumerate (and reproduce in an examination). In fact, there can be differences of opinion, and even disagreements about the meanings of these terms and some people may go so far as to say that neither scientific method nor scientific temper exist! Our idea is that the present study should enable you to judge for yourself and if you feel interested, you can read other books on this subject. If you are convinced that it makes sense, then you can perhaps start to practise it in your day to day life.

34.2 BROAD PERCEPTION OF SCIENCE

Can we define science? A layman or even an illiterate person has some vague idea about science. Perhaps, in his mind such marvels as transmission of music and pictures to great distances, huge aeroplanes transporting hundreds of people from one place to another, brilliant man-made satellites crossing the sky at night are in some way related to science. Some may rightly think of life saving drugs being related to science, and others may think of life saving drugs being related to science, and others may think of all the materials which we use everyday, from the bath mug to the ball-point pen, which have something to do with science. In fact, how intensely our life depends on modern discoveries is brought out very well in a small paragraph in a book by Nail Postmen and Charles Weingartner entitled **Teaching as a Subversive Activity.** This is the quotation:

".... a lot of things have happened in this century and most of them plug into the wall. ...Imagine that your home, and all other homes and buildings in your neighbourhood have been cordoned off, and from them will be removed all the electric and electronic inventions that have appeared in the last 50 years... But there won't be any (movies). Nor will there be L.P. records, tapes, radio, telephone, or telegraph. If you are thinking that the absence of the media would only affect your entertainment and information, remember that, at some point, your electric lights would be removed, your refrigerator and your heating system, and your airconditions. In short, you would have to be a totally different person from what you are, in order to survive for more than a day."

But, this feel for science or the dependence of our life on science, does not constitute a definition of science. Science and related technology have so seeped through every aspect of our life that we sometimes take them for granted and do not know how things we use are produced. How many of you wonder how black lead is put inside the pencils we use, or how the tiny round balls used in ball point pens are produced so perfectly. But all such processes as well as products involve science.

If in search of a definition, we examine history and see when “science” was born, we will again not be successful because no sooner had the human species evolved about a hundred thousand years ago, then men and women started looking at their environment and doing things, consisting of differentiating between edible and non-edible fruits, leaves, barks and roots. Man was driven by necessity as well as curiosity to explore, discover, experiment and explain things that happened to be around him. Thus, scientific activity was an integral part of human existence. No doubt, some specialization must have started quite early so that some became craftsmen of different kinds, some were attracted by priesthood, while others became healers and later medical men, astrologers and later astronomers, or alchemists and their modern versions. But, today, we are again witnessing, through the pervasion of science in every aspect of life, that every one of us is engaged in some activity related to science. Naturally, such a wide ranging human activity can hardly be confined or described in a few lines or defined.

In fact, one of the most outstanding scientists and historians of science, Prof. J.D. Bernal says in his book **Science in History:** “My experience and knowledge have convinced me that my attempted definition, and there have been many, can only express more or less inadequately one of the aspects, often a minor one, that it has had at some period of its growth.... to a human activity which is itself only an inseparable aspects of the unique and unrepeatable process of social evolution, the idea of definition does not strictly apply.”

34.3 ASPECTS AND APPLICATIONS OF SCIENCE

In order to have a better grasp of what we might mean when we use the word science, we can look at various aspect of science.

The first and the most obvious aspect is that science refers to a tremendous fund of systematised knowledge that the human race has built up over the entire period of its existence, but perhaps, more so in the ten thousand years of civilization. In fact, the most dramatic advances have been made in the last few hundred years. This knowledge covers everything from particles smaller than the atom to the great system of planets, stars and galaxies in the sky. It covers all plants and animals, everything about health and disease, about food and medicine. It encompasses extensive knowledge of the human body and the mind. Since the test of the pudding is said to be in the eating, the dependability of scientific knowledge and the wonderful generalizations and “laws” made therefrom, is tested by the various applications of science - flying aeroplanes, growing food, producing thousands of articles used by us in daily life and harnessing energy in a great variety of forms. A remarkable feature of this wealth of knowledge is that it is incomplete. The more we know, the more questions arise about things which are on the boundary line between the known and the unknown. New facts are, thus, continuously discovered and new theories are often needed to explain these new facts together with the old ones. Knowledge is, therefore, growing fat, in proportion to the existing body of knowledge. It is said that the growth of scientific knowledge is “exponential”. Some estimates express the idea differently ; they say that at present knowledge is doubling itself in about ten years.

34.3.1 Dynamic Nature of Science

It is obvious that scientific knowledge is not at a standstill; on the contrary, it is dynamic. And the best scientific workers are those who are doing the most of alter, modify or totally re-explain scientific knowledge. This is infact, what creativity is all about and is much valued. Such is not often the case with other kinds of knowledge - where being stationary or immutable may be considered a virtue; with regard to religious knowledge, for example; those who are constantly trying to alter or modify it may get into trouble.

34.3.2 Research as an Aspect in Science

The second aspect is related to the first, because the unending search for new knowledge, which cannot be carried on without taking into account what knowledge already exists, required a vast network of institutions devoted to scientific education and research. For an individual, getting into the scientific stream means many years of education, and those human qualities which may be called dedication and commitment to learning. Those who superficially know a few facts, or perhaps cram them in order to pass examinations can really not learn science; they cannot get into its spirit, and of course, they can hardly apply it for the batterment of society.

Education and research require communication. Therefore, publication of scientific books and journals (carrying research information) is a big industry. Millions of books and tens of thousands of journals are published in all languages every year. And now, for the education of the public, video and audio cassettes are made and shown and broadcast in practically every country. Millions of scientists are involved in this activity, this trade or this profession. Furthermore, scientific equipment is needed for the classroom as also for the research establishments. Some of the sophisticated equipment is extremely expensive and it is increasingly the practice to set up cooperative laboratories - for example, large telescopes, machines to accelerate charged particles, or to develop high power lasers - with the participation of several countries on several research agencies. In Geneva, for example, the European countries have a Common Centre for Nuclear Research (CERN); in India the University Grants Commission has created a centre for research in nuclear science by the universities of the country. This Nuclear Science Centre is in Delhi. This vast network of communication of results of scientific research, and of cooperation in performing expensive or special experiments gives an international character to scientific activity and requires freedom of transferring scientific information and knowledge.

34.3.3 Science as an Agent of Change in Society

A third aspect of science is the use that society makes of it. Science and technology are at the back of producing every single article that man uses today. Science is indeed at the root of all productive activity. Look at agriculture, which is perhaps closest to nature, and your may think that wheat, rice or vegetables perhaps grow “naturally”. In the present stage of our civilization, they do not. One needs the proper seed which is carefully produced by experts. The land, if it is large, requires machines to plough it. Fertilizers and pesticides are produced in big factories before they are used in agriculture. Water is often provided from tube wells which require electric power. The storage of grain again requires the help of science and technology so that termites and rodents do not ruin what has been so laboriously produced.

Science and technology are being constantly and deliberately used to improve products or to reduce the cost of producing articles which are traded. Cloth produced by technologies such as the “charkha” is arguably, neither cheap nor as fine as that produced by modern fibres in modern mills. Therefore, if any country wishes to sell its products in the national or international market,

it will have to so arrange matters that the best of science and technology are available for the improvement of its products. Research and development are necessary for this purpose, and these improvements in products not only provide advantages in trade, but in turn, lead to further development and growth of science. It is said, by at least some experts in sociology and economics, that it is the means of productions. For example, in old fashioned agriculture, people had to live where the fields were - social and civic life which could be possible under those conditions (which we call rural) is very different from city life which is based on production by machines set up in a factory, requiring workers, engineers, administrators, etc., to live altogether in cities. In this sense, when science changes the means of production, it forces social and economic changes to occur. Of course, not all these changes may really be in our interest.

Unfortunately, different human societies have also fought each other. At first, it might have been to capture fertile fields, pastures, forests or mineral deposits. For the last few centuries, wars have been fought to capture entire countries so as to benefit from their natural wealth, and the arts and crafts of their people, and for "marketing" the products of the victorious countries at highly favourable terms. India became a "colony" of the British in this sense. But, wars require weapons - which also have to be continuously improved upon - from the sword to the gun and the machine gun, from the old catapults to cannons and missiles - and bombs carried by aeroplanes and rockets.

The ultimate weapon is the nuclear bomb which is so destructive that just a 100 big ones can wipe out all life from the earth. Here too, science and technology are crucial. A country backward in science will only have to depend on the mercy of others, or it will have to obtain weapons from others who will then dominate it. That is, lack of science and related efforts to develop technology, agriculture and industry would mean loss of sovereignty - independence in name, but not in reality. All the developing and poor countries are facing this dilemma and threat.

The power and scope of science will, perhaps, become clear to you from this brief discussion.

Check Your Progress 1

Note: I) Use the space given below for your answers.
ii) Check your answer with the model answers given at the end of this unit.

1) What does Science mean to you? Explain in your words.

.....
.....
.....
.....…
……..

2) Briefly comment on different aspects of science.

.....
.....
.....
.....…
……..

34.4 SCIENCE AND SCIENTIFIC METHOD

One wonders how scientific knowledge has grown so rapidly, and how economic and social life and even politics have been so much influenced by the realistic and reliable knowledge of science. The answer lies in the method and processes by which scientific knowledge is acquired and rigorously tested. This method will be explained below, and you will see that it is essentially simple, although, in the beginning, over a period of many centuries, it had to compete and contend with other methods of arriving at new knowledge.

34.4.1 Objectivity

The method of science depends firmly on most carefully observing things, phenomena or happenings, and keeping a record of the conditions under which the observations are made. For example, movements of planets and stars were observed for long periods, year after year, by people situated in different parts of the world, and from this information, the movements of the heavenly bodies were constructed so as to be able to calculate positions, velocities and either regularities or irregularities of their passage. Another example; when someone is ill, all symptoms are carefully noted and if any food, medicine or treatment makes the patient feel better or worse, it is also recorded. The observations have to be entirely “objective”: that is, if there is a traditional belief about what is being observed, it is not allowed to affect the observations. If the observer has personal views for prejudices they are also put aside. This objectivity tends to ensure for example that, for a given disease many observers in different parts of the world will have similar findings. It increases the reliability of the knowledge thus gained.

34.4.2 Experimentation

Sometimes, it is possible to increase the scope of the observations by going to the field, moving around to different places and exploring. One can look for plants as they exist in different environments, or for minerals on the surface or below the ground. At other times, a situation can be artificially created and the consequences carefully observed. For example, a plant may be kept away from sunlight, in the dark, and its behaviour or condition may be watched. This kind of process is called `Experimentation’. Nowadays, of course, there are instruments which greatly enhance human capacity to observe. Telescopes or microscopes may enable us to see things which are otherwise invisible or cannot be seen clearly enough in details. Experiments can be of great many kinds, including such extraordinary things as watching the behaviour of human beings when they are put in a rocket and suddenly accelerated to fly at great speeds, or under unnatural conditions - such as without the gravitational force of the earth.

5 What do you mean, will it work? How do we know, young man, till we test it!

Experimenting, exploring and observing leads to collection of a lot of information - some of which may be descriptive, and some quantitative or a set of measurements. All such information may be called "Data", and it leads to the next step, which is very important. The step is "Analysis" of the data. The data is examined, put in tabular form, or graphical form or fed to a computer, but ultimately human reasoning is exercised to draw conclusions from it. Sometimes, the data shows discrepancies and makes it necessary to make further observations; at other times, it may contradict what was known earlier and may lead to rethinking about old theories. General rules of behaviour are often deduced, leading to the formulation of conclusions which are called `Hypotheses'. The important feature is that, what is really happening is, established without overlooking any facts or observations, particularly the inconvenient facts or observations.

In scientific work, there is usually another round of observations or experiments to verify the conclusions or the hypotheses - before giving out an authentic law of any behaviour of a living or non-living thing. We use the tentative law to predict some new observation and see if it really happens. If it does, the law is confirmed. Of course, a even a well established law, may be challenged if new evidence or observation is reported. Hence, improvement and refinement is going on all the time as knowledge grows.

You may not that scientific knowledge is deeply related to reality or to the actual way things are and how they behave. This is the reason why knowledge can be applied to design new products and processes, whether they be aeroplanes, or submarines, or lifesaving drugs, or new breeds of plants and animals.

Before the establishment of the scientific method of acquiring knowledge, some believed that knowledge is really "revealed"; that it comes as an inspiration from within. Others believed that if we contemplated enough or perhaps retired from life, went into seclusion, and thought hard, we would get knowledge. Imagination and speculation were considered to be another source of knowledge. Of course, imagination and speculation, hard thinking as well as inspiration or inspiration or intuition are all necessary, but, access to a lot of objective information, systematically gathered and analysed have to be the foundation of any piece of reliable knowledge. The test of reliability is application and practice.

The scientific method which we have just described has not only advanced science and its application in our society, but it has also been used in social sciences and humanities. More interestingly, we use it every day in all aspects of our life, without realising that we are using the method of science. We observe traffic on a road, mentally analyse the data and predict that crossing the road is possible at such and such speed and direction. We observe around ourselves and plan a course of action in short or even long term future. Only when proper information or data is missing, we "guess" what we ought to do and our action may be called inspirational, or an act of faith. However, human behaviour is usually a curious mix of the rational and the irrational, the sensible and the senseless. This is because most people are not clearly aware of the scientific method so that they can reduce the scope of irrational behaviour. They are unable to check and scrutinize their private conduct. We have, therefore, to look for human characteristics or attitudes or the mental frame which corresponds to the scientific method.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answer with the model answers given at the end of this unit.

1) Mention some of the changes in everyday life brought about by the development of science.

.....
.....
.....
.....…
……..

2) Mention a few incidents in every life where you find unscientific thinking predominates.

.....
.....
.....
.....…
……..

34.5 SCIENTIFIC TEMPER AND JAWAHARLAL NEHRU

The mental attitude which is behind the method of acquiring reliable and practical knowledge may be called the "Scientific Temper". This phrase has been used in India perhaps because our first Prime Minister, Jawaharlal Nehru was very fond of using it. He was keen that we should not learn science superficially; i.e. just the facts of biology or chemistry and physics. He wanted people to possess scientific temper so that they could be better scientists, better citizens and capable of governing their personal thoughts and actions in a scientific manner.

It would, perhaps, interest you to read just a short extract from the Presidential address given by Nehru to the Indian Science Congress session held in Delhi in 1947. The whole context is very significant. To quote:

“It is a tragedy that when these enormous forces (of science) are available in the world for beneficial purposes and for raising human standards to undreamt of heights, people should still think of war and conflict and should still maintain social and economic structures which promote monopoly and create differences in standards of wealth between various groups and people. I invite all of you who are present here, young men and old in the field of science to think in these larger terms of India’s future and become crusaders for a rapid bettering of the (condition) of the 400 millions in India. I do believe firmly that the only right approach to the world problems and to our national problems is the approach of science, that is to say, of the spirit and method of science”.

34.5.1 Essential Requirements of Scientific Temper

So what are some of the attitudes of mind that lead to the establishment of the scientific method and hence, to the rapid growth of science and its applications?

The starting point may be an attitude of mental activism, as opposed to mental lethargy. This activism leads to a certain restlessness and curiosity, the spirit or the urge to find and discover. The world is full of mysteries, of unanswered questions, of problems that are awaiting solution and the mind should be keyed not towards passivity and resignation, but towards venturing out and striving to discover and do. In every day life, it would mean a deep interest in whatever activity one is engaged in and making an effort to understand, by asking searching questions and seeking their answer.

This is related to another attitude, and that is of not accepting answers without scrutiny. You will find the tendency is very common to accept views and opinions simply,because tradionally we have accepted these views, or some very important persons or say a book which is highly esteemed has expressed the views. But, the scientific method requires solid information and incontrovertible data, and then suitable analysis before accepting anything. We all know that we knew much less a hundred years ago or a thousand years ago; hence, all views handed down to us by tradition are not to be unquestioningly accepted. One would certainly find many of traditional ideas to be sound because they were based on a lot of observation, but this does not make all traditional ideas to be reasonable and sound. So, one has to be critical and selective in examining and accepting readily available ideas, theories and explanations. It is common knowledge that a lot of prejudice about other people speaking other languages, living in distant parts of the country or the world, belonging to different religions or castes or races is passed on from generation to generation, family to family through its uncritical acceptance.Many beliefs and superstitions fall in this category. The scientific attitude requires objectively, not rushing into ready made opinions but patient observation and exploration and then by only forming an opinion. Scientific attitude is, thus, more flexible and open. If you are inquisitive and ask questions, then you should examine the data or evidence, and you cannot afford to be dogmatic and single-minded in such a case. You have to be open to change your opinion if the evidence takes you in that direction.

A great British scientist who voluntarily settled down in India and died here serving our people, J.B.S. Haldane, wrote a book called Possible Worlds where he wrote as follows:

“We are taught that faith is virtue. This is obviously true in some cases, and to my mind false in others... Nevertheless, at the present time I believe that mankind is suffering from too much, rather than too little faith, and it is doubt rather than faith that must be preached. I am not thinking wholly or even mainly of faith in any religion but simply of the habit of taking things for granted ... Modern science began with great acts of doubt. Copernicus doubted that the sun went round the earth. Galileo that heavy bodies fell faster than light ones. Harvey that the blood flowed into the tissues through the veins....”.

Questioning and doubt should not lead to suspense and inaction, but to greater activity in looking for evidence, exploration and analysis in order to formulate dependable opinions and hypotheses. Analysis is again a rational process- reasoning is applied to examine the data and draw conclusions from it. First of all there should be enough data to arrive at a general conclusion. It should not be like the old saying” an Englishman saw an Indian spitting in London and concluded that all Indians are dirty.” in practice, we do a lot of this kind of false generalisation; for instance, our opinions about the living styles and social practices of people of the minority groups are often based on slender evidence. opinions about sikhs or Gorkhas or Muslims or Parses in our country are often like that.

You should be prepared to accept the conclusions which are derived from sound application of reason, even though they may go against your favourite ideas or ideas widely held by people. In other words, one should not be inhibited, or should not shy away, from accepting ideas based on reason. Openness of mind and absence of dogmatism are the hall marks of the scientific temper.

Lastly, knowing that the world is so varied and we continue to live in a period when a great deal is not clearly known or understood, it would be part of a scientific attitude to have humility rather than arrogance in holding and expressing views. We cannot be too cocksure about many things and hence, there should be no obstinacy in holding on to a view; instead, one should be prepared to change one’s view of a particular thing or matter. On the other hand, all the past centuries of human achievement should give us confidence in the ability of science to remove ignorance and to solve perhaps tomorrow, the problems which seem unsolvable today. Nothing, in that sense, is beyond our power. Confidence in human endeavour is also the basis of all active work to discover, explore and create. This is a far cry from fatalism according to which our lives are not made by us but by forces beyond our control, and we are helpless pawns in a game played by the creator. These are some of the attributes of a scientific temper - in addition to such obvious things as hard and sustained work, and integrity in one’s dealings and actions.

It is appropriate to close this unit with another eloquent quotation from Nehru. This I from his celebrated book **Discovery of India.**

“The applications of science are inevitable and unavoidable for all countries and peoples today. But something more than its applications is necessary. It is the scientific approach, the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on pre-conceived theory, the hard discipline of the mind- all this is necessary, not merely for the application of science but for life itself and the solution of its many problems.”

Check Your Progress 3

Note: i) Use the space given below for your answers.

ii) Check your answer with the model answers given at the end of this unit.

1) What is `Scientific Temper'?

.....
.....
.....
.....…
……..

2) Comment in a few words on Negro's views on the scientific temper.

.....
.....
.....
.....…
……..

3) What qualities do your think are necessary for acquiring a scientific temper?

.....
.....
.....
.....…
……..

34.6 LET US SUM UP

In this unit we have deliberated upon what scientific temper is, and why it is so important for every citizen of our country. As we have been reading, science has changed our life in almost every possible way, but many of our attitudes are unscientific or pre-scientific. These unscientific or even anti-scientific values and attitudes are often the basis of very serious negative social developments and processes e.g. communal or reactionary ideas or attitudes. It is with this in mind that leaders of our national movement, including our first Prime Minister Jawaharlal Nehru, stressed the importance of acquiring a scientific temper.

34.7 KEY WORDS

Data: a series of observations, measurements or facts; information that is recorded.

Galaxy: a group of stars held together by gravitational attraction.

Hypothesis: a suggested explanation for a group of facts or phenomena, either accepted as a basis for further verification or accepted as likely to be true.

Pesticide: a chemical used for killing pests, esp. insects.

Satellite: a celestial body or man-made device orbiting around a planet or as a star.

34.8 SOME USEFUL BOOKS

Bernal J.D., 1968, **The Social Function of Science**, M.I.I. Press.

David, Ben, J., 1973, **The Scientists Role in Society**, Prentice Hall.

Haldane, J.B.S., 1958, **The Unity and Diversity of Life**, New Delhi, (Ministry of Information and Broadcasting, Publication Division).

Malhotra, P.L. (ed), 1984 **Nehru: An Anthology for Young Readers**, New Delhi, NCERT, pp. 183-210.

Narasimhaiah, H., 1987, **Science, Nonscience and the Paranormal**, The Bangalore Science Forum, Bangalore.

Ravety, J.R. 1973, **Scientific Knowledge and its Social Problems**, London, Penguin.

UNESCO, 1971, **An Essay on the Origin and Organisation of National Science Policies**, Part I.

34.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) See Sections 3.2 and 34.3.
2) See Section 34.3

Check Your Progress 2

1) The development of science has led to a tremendous expansion of our knowledge. It has also led to an enhanced degree or orderliness and predictability in our day to day affairs. On a more tangible level, it has brought benefits such as an increased life span. The changes are negative also; viz., pollution of the environment, etc.

2) The various rituals, belief in mysticism and occultism could be cited as some instances of unscientific thinking predominating in our day to day life. Of course, many in our country and elsewhere would not agree with this!

Check Your Progress 3

1) It is an orientation of mind that aims at taking an objective view of life.
2) Nehru was against the largely ritualistic and fatalistic mental framework of his countrymen and women. He emphasised mental activitism and dynamism.

3) Curiosity, independent bent on mind, ability to rise above one's personal belief system, etc.