On Science Education and Scientific Research

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Today science appears to have acquired an unprecedented awareness and popular appeal; thanks largely to its applications to technologies such as telecommunications, transportation, radio and television, computers, and electrical kitchen gadgetry and ever increasing number of applications; which bring comfort and luxury and relief from drudgery for a large number of human beings around the world. To be sure, there has been a dark side to the applications of science, namely productions of the instruments of annihilation of the human kind, nay the whole creation – the animal and the vegetation kingdom – if the human being inhabiting this planet so desires. This has led to an anti-science wave among a section of the social scientists. But is science to blame if some power ambitious people have hijacked and vulgarised science for their own ambitions? As long as that dark side of the character of human being exists, such exploitation and distortions will continue to occur.

Today we tend to put 'science and technology' together as almost a single word. Science and technology to many people appear almost synonymous with each other or at least as inseparable. While technology cannot exist without science, it is also true that deeper advancement in science requires what one many call technological innovations. Yet science is something entirely different in spirit from technology and, therefore, will ever stand above blame if we should only realise and grasp the true spirit of science. What then is Science?

What is Science?

Science is nature itself and doing science means appreciation of the marvels of nature happening all around us. The study of science means trying to understand the ways of nature by making inquiries. In as much as any living being is a product of nature and has to learn to live with it after its birth, it begins to learn about the ways of nature and how to adjust itself with the environment provided to it for its habitation. The inquiry could be intuitive as most of us are constantly doing and thereby learning about nature. To that extent, there is a scientist in every one of us. Perhaps, the greatest of all intuitive scientists is the 'child'. Its restless hands and eyes and its alert ears and other sensory organs are the most furious inquirers and explorers. They are constantly seeing and feeling the nature and learning about its ways (the laws). The inquiry is the essence of the learning process. When the child begins to talk, he begins to verbalise his inquiries. They become more explicit and specific. He asks a variety of questions about, among other things, the natural processes around him.

If the natural learning process of the child through inquiries is allowed to develop to its full play, and properly responded to, the scientific faculties of the child will develop fully, evolving him into a creative scientist, an engineer or at least a scientifically tempered member of the society.

Unfortunately, most of the adults around him including his parents may find his inquiries bothersome and discourage him from asking questions. The learning process is thereby curtailed. At school also, the

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process of education is information rather than inquiry oriented. Inquiries are by and large discouraged while acquisition and quick retrieval of information is accorded high premium. The examination is also information oriented and the acquisition of high percentage of marks is regarded as the sole index of high performance. T V programmes which glorify the retrieval of encyclopaedic information only reinforce the wrong values of the information culture. Departure from conforming to these standardised and socially applauded sets of values would be considered as queer and may even be regarded as dull-witted. This may be the beginning of asphyxiation of creativity in a student. Yet there exist many well-known persons who refuse to be subdued by the stifling forces of the system and have managed to keep their spirit of inquiry alive as also their creativity. What should then be a proper science education that brings out the best of creative talents of a student to the fore?

Science Education

When we talk of science education in the context of the present day imperatives, we cannot ignore the pragmatic aspects. We cannot, for instance, ignore the fact that a large number of students who take science courses do so with a view to a career in engineering, medicine and other professional applied fields. These are important aspects that have implications for the evolution and development of the society at large. But these are not the issues that I would like to address at the present juncture. Suffice it to say that a proper science education should be beneficial to also those planning to take up professional courses. It is the encouragement of creativity that should be the aim of science education and creativity ought to be valued in all professions.

I would, however, like to address the question of science education from the point of view of creativity in the pursuit of science itself.

When the legendary 'apple' fell on Newton's head and thereby literally awakened him to the realization of the existence of a force that attracted it towards the earth, he was not the first man who saw the apple fall. But surely it was the first time he realized the apple fall, for it did initiate in his mind the inquiry: why? Or when Einstein while travelling by a streetcar in Bern was set into thinking about the relativity of motion, which culminated later into the formulation of the 'relativity theory' he wasn't the first man to have travelled in a streetcar. What then distinguished these men from others? It is their power of observation and inquisitiveness which enables them to notice things, phenomena or processes which others pass by, and to institute inquiries about them. It is their ability to see astonishment in certain happenings which others take for granted. It is their mental analytical ability that enables them to analyse and classify observations into logical structures. It is the sharpness of their perception of physical phenomenon that gives them delight in having found something new and astonishing. It is their disposition to view a set of facts with a different angle and perspective that allows them to discover a higher order in the scheme of things, than was hitherto known. Thus the heliocentric view of our solar system by Copernicus is one such example that provided in fact the starting point of not only our present hierarchical view of the universe, but also the basis for the Kepler's laws which, in turn, enabled Newton to formulate the science of mechanics.

Thus, in relation to 'science education', we ought to ask ourselves if the science education being imparted to our young minds is encouraging any of the above mentioned traits. Far from it! On the contrary, our science education represents, willy-nilly, a systematic though inadvertent attempt at curbing all these traits and consequently creativity. I am not suggesting, of course, that it is a deliberate attempt. But the total system appears to be so insensitive, rigid and impervious to suggestions for liberalization and improvement that it does give such an impression. Witness for example, the horrendous science text books that continue to be prescribed in some states for use of our students, which are full of unpardonable howlers. When it is the observations of natural phenomenon by direct visual perception that should be encouraged, it is only through pictures in black and white that a student is taught how a beautiful plant, a flower or a colorful rock is supposed to look! When the characteristics of a phenomenon ought to be learnt by a student through observations, he is asked to cram these properties as enumerated most dryly in the colorless science textbooks. These, in turn, are supposed to be reproduced in examination and a high percentage of marks obtained are all what is regarded as important and relevant. What exists thus amounts to an antithesis of creativity. It is amazing that this state of affairs has been allowed to go on year after year even though the stifling effects of such a system have been repeatedly debated and pointed out. Yet for some inexplicable reasons, the system continues. Is it, therefore, any surprise that our assets of creativity are as low as they are?

A country that is credited with having nurtured a large number of creative physicists during almost the first half of the present century, namely Germany, had a rather free academic environment. I quote from Max Born about the state of the educational system and associated academic environment prevalent at the time when he got his education.

"In Germany at that period... (there was) complete academic freedom at the University. There was, in most cases, no strict syllabus, no supervision of attendance, no examinations except the final ones. Every student could select the lectures he liked best. It was his own responsibility to build up a body of knowledge sufficient for the final examination which were either for a professional certificate or for a doctor's degree or both. Thus, I made up a rather mixed programme for my first year, including physics, chemistry, zoology, general philosophy and logic, mathematics and astronomy..."

If we compare this system then prevalent in Germany (as I suppose it must also be now) with what exists in our country, the contrast is stark. Our system is coercive in more than one sense. Students are coerced to study subjects which they may not relish: they are coerced by parents and society to secure high percentage of aggregate marks regardless and oblivious of any real learning in the process. Most students regardless of their aptitude are coerced into a chosen few professional directions. At the end of the assembly line, one thus gets only two or three kinds of objects 'round', 'cubic' and may be 'cylindrical'. Where is then any scope for creativity? Creativity requires that a student be encouraged to develop his innate desires and aptitudes and a choice should be available to him – a choice to develop his own personality and his own individuality.

To be sure, a student today is, by and large, more informed about scientific advancements in the world compared to his counterpart a generation ago. I have also come across greatly enthusiastic students at the high school level. I have also met some very sincere and interested teachers. But information is not education. Excessive information can and does lead to indigestion. Students ought to be allowed time to digest what they are taught. And they ought to be taught in small digestible doses.

There has been a tendency for some time now to push down higher level courses into lower classes. Thus what was earlier a part of the BSc syllabus is being introduced in the higher secondary and the process continues all down the line. This compression is sought to be justified by saying that in this fast developing world of science, a student must know the latest, otherwise, he would be left behind. And, if new modern developments have to be taught in BSc, then old things must be pushed down to XII standard and so on. Moreover, the panel of mathematicians who design the mathematics courses see in every student a potential mathematician and so would want him to learn all the mathematics they can teach. The panel of physicists and chemists do likewise and keep on enlarging the syllabi for the XII standard students. This is not only counter-productive and counter-educational, but amounts to subjecting the tender minds to a kind of academic violence and torture. The number of suicide cases that are reported during the examination time are not unrelated to this fact.

It is extremely urgent that we give completely new directions to not only our science education, but adopt an entirely different approach to our education itself.

Scientific Research

Scientific research means an advancement of knowledge over what exists at any given time. While science education ought to aim at learning about the existing knowledge in a methodical way and at developing keen sense of observation and analytical mental ability, scientific research means a further exploration of nature beyond the present frontiers of knowledge using the skills and the power of observation and analysis acquired in the process of learning science.

Thus our ability to do scientific research at the highest international level is intimately related to our training during the process of education and to our attitude to science research. Of course, scientific research is, in general, both basic and applied. While both types of research are extremely important for our country, it is not the type but the quality of research that is the central issue.

Science research has usually progressed by leaps that have been taken by individuals with unusual power of observation and insight. One can recall the names of Copernicus. Kepler, Newton, Leibnitz, Euler, Lagrange, Hamilton, Kelvin, Clausius, Faraday, Maxwell, Einstein, Bohr, Heisenberg, Schrödinger and Dirac. The list is, of course, not complete. These names stand enshrined in the annals of science. Among the classical physicists, the names of Copernicus, Kepler and Newton on the one hand, and Faraday and Maxwell on the other hand stand out most prominently for while the former gave us science of mechanics, the latter gave us the laws of electrodynamics, the two cornerstones of classical physics.

After such leaps, there still remains a large amount of work to be done which consists in applying the laws so discovered to a large body of phenomena where these laws could be applicable. A large number of first rate physicists both experimental and theoretical, belong to this category. This is also a very important class of physicists because they are the ones who help establish and expand the regime of validity of the laws of nature propounded so far through painstaking experimental and associated theoretical work. These may not appear in comparison to be so glorifying and rewarding at first sight. However, every scientific investigation well conceived and well done is important, for therein lies the opportunity of a new finding which may be defying the existing laws and may be pointing to the existence of new ones. Thus, the painstaking observations of the 'black body spectrum' had in them the germs of the most important discovery of the twentieth century, namely the 'quantum theory', for it could not be explained in terms of the laws of classical physics.

What are the motivations of a person who opts for a career in scientific research? It can not be the riches of the conventional kind, for riches there are not in this career. Many who have opted for such a career, in its true spirit, did so, perhaps, with a secret wish that may be some day, their name may be counted among those great physicists who have inspired them. In some sense, they were daydreamers, whether one succeeded or not is a different matter, but such a wish is a very human sentiment and does provide the person with a motivation to put in his/her very best. And while one is pursuing one's work with this kind of wish and motivation, one may discover yet another kind of motivation for pursuing science, for simply the pleasure of discovering something entirely new and which nobody else besides him knows. Planck apparently had this realization when (reportedly) walking with his son in a garden, he is supposed to have told him that he seems to have "made a discovery comparable only to the discoveries of Newton". To people of that class, science is an obsession which they would pursue even under the heaviest of odds driven only by the desire of learning about what lies beyond: which may sometimes even be beyond their own capacities.

David Hull in his review of the book *The Selfish Gene*, by Richard Dawkins, has written (*Nature* 342, 319 – 320, 1989) "scientists give every appearance of being addicts and science is their vice". "In the addiction stakes", writes John Galloway (*Nature* 343, 707, 1990) "Marie Curie was a 200-a-day woman. Not for her a fellowship at a comfortable Oxford College: she worked 12 hours a day in a leaky hanger in the backyard in condition that no self respecting heavy labourer would have tolerated". And she worked for nothing. That's what I call addiction.

What are the motivations in today's world of science? Times have of course, changed and with it our social mores and attitudes as well as the quality of motivations. Earlier science was more or less an elitist profession confined essentially to university departments. With the spread of education and proliferation of science and ever-expanding volume of scientific research, a host of extraneous motivations have made an entry into the pursuit of science. Scientific pursuit appears to have degenerated to a state of any other profession. Where pursuit of scientific truth and the pleasure of the prospects of achieving it were the major motivating factors, quick visibility is the most desired objective and motivation today. There seems to be a considerable impatience to achieve it and consequent frustration arising from not being accorded

the recognition and visibility that one believes one deserves. The emphasis inevitably shifts from the quality to quantity because the quantity tends to carry its own weight and impresses in the absence of a critical evaluation of the work. But the emphasis on quantity can lead to indiscrimination in the choice of problems that one chooses to address. A fall in the standards of research is consequently a distinct possibility.

To guard against the falling of standards and slippage in one's own value system one has to constantly remind oneself of the values that have been upheld by all those who have passed on to us the magnificent scientific edifice built by them painstakingly brick by brick. We must not only try to preserve this magnificent heritage, but also contribute to it, if we can, by adding another piece somewhere to enhance its structural beauty, but must certainly not do anything to tarnish it.

Once one sets for himself such high standards of achievement, life is certainly not easy. One tries hard and is constantly haunted by a sense of failure because the successes by this yardstick are few if at all and failures numerous.

Sir C V Raman is reported to have said that he has been a failure as a scientist. If one did not know the real meaning behind this statement, one would be astonished at this coming from Raman, our only Nobel Laureate in science. But his sense of failure, if one were to believe it, came, according to him, when he compared himself with Lord Rayleigh and Lord Kelvin and other physicists of that calibre. The point of the story is the level at which one wants to pitch one's efforts and achievement and one's level of satisfaction without being deflected.

Science has always been highly competitive, but it is much more so today than ever before. Really fundamental discoveries are few and far between. But they are still there and they still beckon and challenge us. We need to listen to their call and go in the right direction and not be lost in the wilderness of the trivia. It is easier said than done. But still there are those who have the passion and strive endlessly to achieve their treasured goal.

Chandrasekhar quotes T S Eliot in his essay (*Nature* 244, 285, 1990):

It is strange, isn't it?
That a man should have a consuming passion
To do something for which he lacks the capacity.

A fool's brain digests philosophy into folly, science into superstition, and art into pedantry. Hence university education.

G B Shaw