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Why a Different Approach to Science Teaching

Abstract

The paper explores different approaches to science teaching and shares an analysis of reflection of the idea of quality science education in the policy and curricular documents. It also presents and analyses some experiences of working with teachers and the implications if that.

The notion of the meaning of good science education has been a contentious debate. The understanding of good science-education has evolved over time in the context of Indian education. Over the last few decades experiments have become an important component of science education in schools. The manner of its articulation and its expression in the materials and methods does not reflect the spirit of understanding of either the notion of science or the possible purpose and the process of learning science. It is not that there are no known efforts from India in this direction and no alternative examples and principles available. But the principles in the policy and the curricular documents and even from the Hoshangabad science education program have been reduced to a few catchwords and rituals. The understanding of science education must consider the nature of science including the meaning and purpose of education. It must also consider its relationship with society including the concern about its hegemonic relationship in some world views. The purpose and the methods apart from all this must also include in some manner the experience and abilities of children. While this is not easy to construct in a simple meaningful manner, the principles can be articulated but their exposition in the classrooms depends on the beliefs and confidence in teachers. Teachers even though enjoying an exploratory experience of experiments and analysis with simple components of generalisation do not feel confident of being able to make such experiences possible for children in the classrooms.

Background

Science teaching has been a major area of interest in pedagogic circles for quite a while. As far back as in 1964, the Kothari Commission's[1] report stressed the need for good quality science education and suggested that ways and means should be found so as to have children conduct experiments and discover principles from the observations of these experiments. It was not easy to set-up a structure which would make experiments possible in the schools. Following this, many other sources have suggested a need to provide scope for children in the elementary schools to conduct experiments. In this direction there have also been attempts to set-up outside the classroom structures that would give children an opportunity to conduct experiments as also to observe events and analyse observations. It has never been an easy task and a variety of hurdles increase the difficulty.

There have been attempts spread across the country to provide science kits to schools so that children could be shown experiments and observe some of the experiments that are given in their books being done. G.P. Tulasi[2a] talks about the 1970's effort of the NCERT in developing and trying out the series 'Science is doing'. Tulasi points out that while in conversations there was a mention and acknowledgement of the fact that children at the primary stage would be at the concrete operational stage and hence only could deal with science and mathematics concepts based on concrete materials (which in the case of science would mean experiments and kits), this was not accepted. The result was the series of books that followed had concrete materials and experiments but not as the core strategy. Experiments were encouraged in them merely as simplistic demonstrations of scientific concepts and principles but not for actually experiencing the process of doing science and engaging with concepts.

These books of the National Council for Education and Training were used by the States across the country put title like "Science let us learn by doing". This on the cover page seemed to be indicating acceptance of the principle that science needs to be learnt through experimentation, the reality was not so. Tulasi in introduction to the book points out that "Several Science text books were available at that time in the market based on the NCERT's syllabus for Science in Primary classes[2b], they were mostly content oriented. Though 'Learning by Doing' is accepted as the best way of learning science, yet 'reading a textbook' and 'listening to the teacher when he reads the book' were very much in use in the primary science classes. It looked that curriculum developers, textbook writers, apparatus designers and teachers had generally gone about their work without taking into consideration the Cognitive Development of primary school children for whom the materials which they produced were intended".

During the same period an effort took root in the Hoshangabad district of Madhya Pradesh which went closer to the stated goals and strategies of science-teaching. Known as HSTP (Hoshangabad Science Teaching Project) this had NCERT as a partner as well. The program expected children to work collectively, conduct experiments, analyse observations, generalise and infer linkages, causes, consequences and their interrelationship. Some of these ideas went in to the preparation of the 1986 National Policy on Education document. The policy document included a section on science education, wherein the need for children having the opportunity to conduct experiments was stressed and it was suggested that changes towards this direction would be welcome.

The Quality Notion in Science-Teaching

The popular discourse in the improvement of the quality of science-teaching has been focused on methods. All kind of methods are spoken about and these also suggest the use of the experience of the learner in some way and seem to also emphasise process skills. The listing of these process skills and the content of science often gets mired in the process and product debate. What ever is considered desirable is suggested but often as optional addenda. These include collaborative work, active experimentation and data processing, using the real life experience in a way to link conceptual elements in the curricular choices with it, etc. There would therefore, be recommendation of experimentation, observing and as so on but as pieces not organically linked to the main body. The explorations in science are as optional projects and hence largely inclined towards exhibits and concrete displayable materials.

The adaptation of the idea of learning by doing and experiencing thus became a buzz word without some of the major elements. These ignored elements were the nature of science and scientific knowledge, process of learning of science in the sense of acquisition of concepts, collective work and dialogical processes, bringing in the experience of the children and constructing on that. In a nut shell what got emphasised from the academic discussions that constructed the NCERT effort and the HSTP were phrases like do experiments, do projects, apply science ideas etc. The basic underlying principles that informed these as one set of possible outcomes were totally missed. The quality discourse in science teaching as well as in other subjects has remained restricted to showing and telling through concrete things missing the underlying principles arising from what we want children to experience, do and learn in the school and the classrooms. The effort to use a richer more comprehensive formulation of quality, which would include the nature of subject, nature of knowledge and the purposes of learning science could not become a part of the wider discourse in the program for a variety of reasons.

Purpose of Science Education

The basic issue that confronts science education therefore, is to escape from the trap of this caricature of quality science education. As pointed out, this relates partly to the meaning of science, its nature and what it means and also partly to what we mean by learning. If we examine the common text-books (Govt or private) being used to teach science in the elementary classes, we would find them full of abstract statements and detailed information that do not relate to the experience of the child and also not perhaps to the nature of science it self. They may have frills of experiments and projects but they are not integral to the method or the materials and hence miss their purpose entirely. Progressively, over the years materials from higher classes have been shifted to the lower classes to balance the so-called "explosion of knowledge". The argument given is that every year new facts are discovered and new information generated, if these are not 'given' to the children, they will not be aware of the direction in which science is progressing. They must be familiar with the definitions of these words and be exposed to all these names with the expectation that the child will be acquainted with these names. This has come from a mis-interpretation of the Kothari Commission's[1] suggestion that as the knowledge is increasing rapidly, we must take cognizance of it and develop in learners a sense of curiosity and capability to be able to acquire the relevant conceptual understanding. The report states, "*There has been a great explosion of knowledge during the last few decades. In a traditional society, the stock of knowledge is limited and grows slowly so that the main aim of education is interpreted to be its preservation. In a modern society, on the other hand, the stock of knowledge is far greater and the pace of its growth is infinitely quicker. One of the main tasks of education in a modern society is to keep pace with this advancement in knowledge. In such a society, knowledge inevitably ceases to be something to be received passively; it is something to be actively discovered."(Clause 1.70 page 18)*

The Commission's report went on to say is that this 'to know' does not mean 'learning by heart'. It further pointed out the need to have science as the basis for technology, industry and agriculture and for strengthening the commitment to free enquiry and the quest for truth encouraging the spirit of enquiry and experimentation to make scientific outlook a part of our life and culture. They pointed out that science loosens the bounds of dogmatism and dispels fear and superstition as also fatalism and passivity. In essence the objectives laid out were, "*The quality of science teaching has also to be raised considerably so as to achieve its proper objectives and purposes, namely, to promote an ever deepening understanding of basic principles, to develop problem-solving and analytical skills and the ability to apply them to the problems of the material environment and social living, and to promote the spirit of enquiry and experimentation.*" *(Clause 1.23 page 7)*

The Education Policy[3] in 1986 and amended in 1992 argued for the need for stronger science education spirit of inquiry, courage to ask questions, creativity, objectivity and an aesthetic ability. It further suggested need to develop problem solving and decision making ability and relate to science to all aspects of daily life. It also argued for promoting science education to everyone even those outside the framework of formal education; a wide set of purposes, that are not linked to passing tests and exams and to knowing facts and details. The National Curriculum Framework 1988[4] reiterated this and hence argued that science and mathematics need to be integral parts of school education up to class 10. The main purpose again was to develop curiosity, scientific method of inquiry and preparation for competent participation in a changing society and culture, with a rational outlook.

As we can see Science education has remained a concern in the policy and in the curriculum documents each one building on the previous. They have underlined and reiterated the twin objectives of scientific temper and curiosity and the use of science to aid development in agriculture and technology. They suggest that science curriculum and teaching should be focussed on doing experiments and analysing the observations from the experiments and the experiences of life to form understanding that is useful and meaningful even as it is rooted in the known principles of science. The science teaching programmes however have been moving in another direction. The direction is increasingly towards what has been described in Tulasi's introduction. The same is reflected in the analyses in the position paper National Focus Group on Teaching developed during NCF-2005 exercise by the NCERT. The National Curriculum Framework for School Education 2000[5] pointed out that the task of the NPE 1986 (92) and the curricular framework of 1988 in improving science education is yet to be completed (pg7). It also adds the need to shift from traditional learning atmosphere to one that encourages exploration, problem-solving and decision making; from prescriptive teaching to participatory, decentralized and interactive group learning. Change from focussing on collection of information to its processing with encouragement to search for patterns and connections. (pg16-17)[6a]. Similarly the position paper on science education 2005 of the NCERT additionally suggests that science education must be actively engaging and involve enquiry, exploration, questioning, debates, application and reflection, leading to theory building and the creation of ideas/positions. (pg 17-18)[6b].

The Notions of Current Science Teaching

In spite of the principles laid out in the NCF 2005 and the position paper, the teaching of science even till secondary and sometime even till senior secondary classes is devoid of experimentation. The general principles that are used to think about the curricular organisation and its transaction include ideas absolutely incongruous with the the principles in policy documents. The popular ideas of quality lay aside all the notions linked to the purposes and use a list of quick fix short cut clues like from simple to complex, from near to far, there is an explosion of knowledge account for that. The other type of folk ideas used are, children need to be exposed to everything, they should be given these in small bits, they must be given useful facts as messages to be remembered as and when they are needed or some exciting discovery takes place. It is not necessary for them to understand these. They would understand them later. They must be given rules to follow to develop correct and ethical behaviour, These and other such principles define the operative notion of quality and this in the context of science education leads to the following as the underlying assumptions for any teaching-learning conceptualisation and practice:

1. There is an assumption that learning is a linear process and equal chunks can be learnt in equal time.
2. It is further assumed that learning, a fact is independent of the development of any other understanding in the child. It is, therefore, not necessary to present the materials in a linked manner and ensure that there are no arbitrary details included. This approach does not need to emphasise articulation of their observations or enunciation and discovery of the rules by children.
3. The information in and about science is considered to be fixed and unquestionable. Everything that experts of different hues and interests consider important for themselves has to be put in.
4. The accepted principle is that everything that is related to the idea needs to be put in for exposure of the children even if briefly and in passing.

In all this, the fact that details of information are changing each moment is totally over-looked. The attempt is to constantly put in more and more to keep pace with information about the developments in various aspects of technology. It is easy to see that there is no way by which the world of children or even material that can be put together by the 'experts' who prepare the books keep pace with information about the developments in various aspects of technology. Because of the principle that children must be given an exposure to everything 'significant; there is very little selection possible based on the learning needs of the children. Most of the material is forced to be put in so that the child is introduced to it. This results in inadequate space being available to workout these ideas in the text-books as well as in the classroom. Over simplifications and metaphoric expressions have to be used to make concrete, abstract information. This often results in gross errors and certainly does mislead students and makes them develop incorrect pictures in their mind.

The materials include examples of experiments but these experiments are often not doable. The authors pick-up the experiments from other books and without trying them include them in the book. In many of these experiments, it is not possible for the teacher to conduct the experiments in the classroom because the instructions are not clear or the kit is not easily accessible or sometimes, even because the expected results are mistakenly anticipated ignoring scientific analysis.

One classic example of this is the experimentation to measure the amount of oxygen in the air. This is to be done by allowing candle to burn in a closed space (glass placed upside down) and then measuring the amount of water that would rise in the glass.

The conclusion of the experiment is often given as 20% water would rise in the glass and the reason is that burning utilises the oxygen and hence the water rises up to fill the space of the burnt oxygen. In this, what is forgotten is that when candle burns carbon dioxide is formed and there is no reduction in the total volume of the gasses making up the air. But the point of importance for the program is the fact of 20% oxygen and the experiment has no other relevance [7].

Since the amount of information and facts are considered to be the important part of the classroom transaction, it is not considered amiss to include information that the child would not otherwise have an experience of. It is also not considered important to make children do experiments and increase their experience base. There is an emphasis of facts and definitions and this makes the text-books unrelated to the experience of child and only focused on what adults think he/she should know. The text of the books, therefore, becomes dense and full of unknown technical words with no relationship to what the child can perceive in her environment. The lack of attention to concept development in the child is apparent throughout the program of science teaching. It is in the nature of instructions put down, in the kind of information given, in the kind of evaluation parameters considered valuable and in the teaching-learning as well as the evaluation processes, etc., as well.

There are Alternatives

It is not as if there are no alternatives, there are many possible ways in which children can be required to do experiments and analyse them as well. The example of the NCERT's efforts over time, of the Bal Vagyanik of the HSTP[8], The little Science[9] developed by the HBCSE and many state Govt books themselves show the possibilities. The important requirement for that is to have a question that we want to explore or a statement that we want to test. Experiment is not a way to remember facts but to experience and learn the process as well as to understand concepts. What they show that this can be done and children given the possibility to observe and analyse the observations to generalise and form answers. The effort of PRASHIKA[10] for the primary classes showed that children not just test hypothesis but also articulate and check their own. It gives many ideas that expect the children to value their observations and analysis. The basis principle has to be as Dewan[11] argues in his paper that experiments have to be with a sense of finding out some things that are not known to the experimenter and not just having to reproduce some numbers. Simple investigative tasks can be found and set up that expect a certain process to be followed.[12]

It is not as if there can only be a few investigative tasks. These can be as many as are and it is merely a question of the attitude. With the right approach there can be many investigative tasks constructed and their pursuit can create more such tasks. All phenomena and even the known experiments have elements that can be investigated for new dimensions. The important thing is to do the exploration and the analysis with an open mind not focussed on reproducing the known answers or even validating them. For example, the rolling of a ball with similar speeds on different surfaces to study the variation in the distance travelled. Or the extent of bounce of a ball from different heights on different kinds of surfaces or the same surface with different types of balls. It is not that these have to be all constructed as experiments to observe, record and analyse data. As we go to the secondary classes and beyond, more be thoughtful experiments requiring predicting the outcome and reasoning out the prediction could be used. For example what happens when you throw a ball up with different jerks upward. How high would it go? What are the forces acting on it once it leaves the hand? Or the task of collecting objects (or just their names) of different kind and predict which will float and which would sink and why? All this, without collecting the data first, thinking about the possibility, thinking of reasons for it and then checking it out if correct.

The Notion of What is Science

The other aspect of what is science and what is knowledge and how sometimes it becomes accepted as scientific knowledge also need to be thought about. In this also embedded is the issue of the direction of the disciplines development, the factor and forces that guide it and the underlying power and economic dynamics. The question of nature of science also needs to confront its relationship with technology and be both aware of their dialectics. The fact is that while technology, power-dynamics and economic considerations have and continue to influence science and the question it investigates, on the other hand the principles discovered themselves give rise to many technological ideas. The comforts, the travail and the tools of constructions and destructions are all available to us now. This relationship yet remains to be included in the science classroom in a nuanced manner. Neither the occasional/strange sources of discovery arising out of the hunt for the technology nor the essence of the mutual symbolising they have often in treatment and in common discussion science and technology get fused into each other. The radical view on the other side is that science is value free and objective and has no relationship to power or technology

We debate the technology and science and continue to analyse it as the mutual influence waxes and wanes (never disappearing altogether, never becoming a complete merger). We are not doing justing to the learning of science. For science needs to be also examined for its choice of concept and challenged in its claim for objective study of world. The issue of which lens of perspective shows what science needs to be analysed too.

There is similarly question of power and hegemony. It is true that science can give away to question the order of things and seeks objective justification from empirical evidence. This does force acceptance of many principal that challenge iniquitous power relations as being unjustified. In principle can also give humans a confidence in themselves and in nature. A sense that largely understood by process and forces arising from known resources and that this set is not yet complete. This to some may mean science would eventually have assumes for everything that happens and to other that it would continue to have to hunt as the answers finds pose more complex questions and hence it would always be a learning field. It would never answer everything not because anything outside but because of the system of knowledge itself. This needs more detailed discussion but that can be done elsewhere. Suffice to say science need not become mystical to accept its inability to give comprehensive explanations. This hegemony is in context of its relationship with nature.

There is also a question of science and hegemony of power on science and the struggle or the lack of its from science to free itself of the push power and structure and give it.

It was argued by the Kothari Commission that Science, by its emphasis on reason and free enquiry, even helps to lessen ideological tensions as they often arise because of adherence to dogma and fanaticism. They add that although presently mostly engaging with the understanding of Nature it is tending to help humans understand themselves in conjunction to the universe. They articulated the hope that the future pursuit of Science would not be mere material affluence and power. The subsequent developments have not quite borne this hope or the hope that Science would develop a temperament that would build in humans rational empathy and a sense of equality.

Hegemony and Science

Besides this question of the relationship of science to construction of values, the issue of its strength and limitation as a truth criteria has also become widely discussed. In this, the hegemony of 'Science' over the modes of knowledge and thinking has also come up in discussions and challenged strongly. In this conversation there are some meaningful arguments that need to be taken cognisance of but a large number are also frivolous. The over done subject centered view of reality cannot provide common meanings. A multitude of such views without notion of judgement, i.e. a set of criteria that would be the basis for making them coherent would cause havoc in sharing a world. Similarly, the hegemony of Science cannot be invoked to defend un-examinable beliefs, therefore Science has to examine its choice of areas of study and evaluate them critically. The opening of the science classroom to explorations of ideas that children form can therefore be an interesting exercise as can be the analysis of the questions studied and not studied by science help learners understand the direction of development of Science and that alternatives to that do and have existed.

It is time that we examine some of our assumptions about the nature of knowledge and how children learn and make more interesting and meaningful science education possible. While the larger questions of hegemony and modes of knowledge is not being addressed the steps of allowing explorations and thinking need to be begun. Unless we give opportunity to children to conduct experiments, record and systematize observations and analyse what is happening in this process, we would not succeed in giving them adequate confidence to become learners. We need to break the notion of disjunction between life and between school and ensure that children are able to carry their ability to explore ideas to their environment and explore and utilise their own observations systematically. It is much more important for a child to be able to absorb and analyze from experience then to remember by rote definitions, formulae and alien names.

The Features of the Alternative

The essential features of the alternative attempt to formulate science education include the insistence that the child must learn the importance of conducting experiments, record as well as systematize observations, analyse them and compare different sets of observations so as to be able to generalize principles. It is important for the child to be able to formulate arguments to explain his or her understanding and to logically connect her experiences with what she does in the classroom. It is much more important to build the confidence for learning science and make the foundation of basic concepts on which the structure of science develops then to have children swamped by information that may be very topical and temporary. In our opinion, it is possible to provide kit materials to schools and ensure that there is a space to store them and it is possible to have teachers trained so as to make possible science classroom that are genuinely discovering answers to questions formulated by the students also. And to develop the foundation of the conceptual structure that will help children to do science in different ways in their life.

We are also aware that there is a balance that needs to be built. It is not desirable to have children discover everything from scratch and allow them to come up with explanations and arguments that are similar to arguments given in Aristotelian times. We are also aware that science is changing and developing all the time and that new words are acquired by science every moment. We also know that in order to become a learner the child must have the basic of the conceptual structures, she would utilise to develop further concepts from her experiences set up. But we feel that there is no point including so much information that entire school programme becomes abstract and meaningless for the child and is totally dictated by what adults consider to be of value for her. In a process of redefining science education these considerations must be kept in mind and we should not make the mistakes made earlier also of keeping the subject needs and the needs as spelt out by the adults as the focus. The focus should be participation, involvement, exploration and change rather than safe conservatism.

Trying an Inquiry Approach with Teachers

As we can see the principles that have been repeatedly articulated have not reached the classrooms as yet. The impediments are many in terms of systems and beliefs of both teachers, administrators and educators. Before it can get into classrooms the idea of exploring has to reach teacher. How far this can go? An example of this is our experience with a small number of teachers over a series of workshops. In these workshops, teachers were taken through tasks to explore the word science, its meaning and the implications of that for its teaching. The experience gave the teachers opportunity to explore Science teaching. The tasks used in the workshops were simple, used simple equipment and had the possibility of easy repeatability. Teachers worked in groups and developed the scope of the set of experiments as they went along. In that process they also extended and widened the inquiry statement as well. The inquiry statements were such that they had no answers available in books or web and hence had to be reasoned out.

The general attitude of teachers to Science including as a learner became clear quickly. Initially, the school teachers showed a nervous anxiety and attempted to answer everything using complex concepts and definitions. They gave the impression of science being a body of known and correct knowledge to be transmitted. They were afraid to draw any conclusion from their observations and even afraid of recording observations as they did not know the correct observations. In their panic, they refused to see even commonsense approach and tried to explain simple phenomena using complex formulations in an attempt to mystify issues.

The other crucial aspect is that once they started the journey almost everyone enjoyed working with their hands, doing the experiments and then thinking openly. There was no expression of boredom, lack of participation or enjoyment while these discussions were taking place. yet there were as few die-hards who refused to touch any equipment and who thought they could answer everything and explain everything from their theory and logic. They denied what they observed as wrong and said the experiments were incorrect as they did not conform to theory.

On the other side was the convenient retreat, 'how do I know what will happen', how can I predict anything. The argument was that the knowledge of science is only empirical. What has happened is for us to see and I would know what would happen in the next case only when it is done. A reluctance to see pattern and linkage between the results. Both these views were based in an understanding of science that it was the business of scientists and experts and laboratories. Both views were unwilling to accept a responsibility of making sense of what was seen and forming ideas to share. It is also important to point out that while they were free in their speculations, they did not want to use the observations of the experiment in any way to inform or structure them.

The other aspect that emerged sharply is the fact that the Science education that all of go through forces us to doubt the experimental data rather than the conceptual predictions in the case of a mismatch between the two. In this, as well in almost all the other workshops too even at the level of textbook writers and trainers of science teachers, there is a lack of appreciation for errors and measurement problems. science is accurate, does not lie and gives absolute answers is the normal belief. When confronted with the problem of the length of a table, they felt that using a better apparatus, the length could be measured exactly. It took some thinking in many discussions as well as their own encouragements for them to be convinced that measurement is always limited by error which may be reduced but can never be dispensed with entirely or that weight of the bob in an oscillating simple pendulum did not give as much of variation of time period as they believed from their science learning. What we realised were that the major challenges before us in developing an alternative of more meaningful Science teaching are:-

1. Lack of openness in teachers about exploring and thinking about new issues.
2. A feeling that it is more important to state and define something in exact words than to think about and develop one's own understanding and consequent definition.
3. Science and its process of development seem to have been entirely left out when they were learning and the way they were taught.
4. Their understanding of science concept is weak and they are unable to think openly and ask a wide variety of questions. They do not feel that process of Science and developing the capability of working according to that process is a valuable asset. For them much of it is a waste of time and they feel compelled to push learning facts as proper Science teaching.
5. There is a desire for a lot of existing information and straight-forward answers. They have statements from different texts that they have read, which they believe and quote

without any basis. Not only is their faith in the textbook deepen but, they also have a tendency to believe anything that has been written and printed. We had discussions on some of the information they had picked from different sources but there was nothing in their experience to back the information. The understanding that they exhibited stemmed from a pedagogy which has taught them to value facts. The struggle of learning about nature and its laws discovering a better understanding about every things around us does not appear to be an active proposition.

6. It becomes important to communicate to the teachers, the necessity for openness about learning of science and present to them the tentativeness of science and its inability to claim final and true answers. Most striking thing about the workshop discussion was that people realised that the fable of the apple falling on the head of Newton is hopelessly inadequate to explain the kind of generalisation that Newton reached. The discussions made them understand that as a science student or as a science teacher the thing to realise is that there was an enormous amount of existing work that was available and served as input for Newton to make the generalisations. Yet what Newton said, what Einstien said, and what great scientists have said recently are all open to question, research, and modifications. This message of tentativeness continues. It is fascinating for people to historically trace the development of understanding/knowledge and realise that science always changes and that there have been no fixed rules in science.

7. We also explore in the workshop of the experiments that were there in the text books and tried to do as many of them as possible. We discovered that it was not easy to do many of the experiments. Some of the experiments did give answers that were different from what was expected. It also emerged that in some of the experiments the expected observations and the reasons given for them were logically fallacious and inappropriate.

   All of us felt uncomfortable about the way experiments were designed and presented in the textbook. What we gathered by looking at the textbooks was that the main purpose of experiments in the text books seems to be to verify and agree to what is being said as a fact. The child or the teacher has to report results after the experiments and invariably the result need to match with the age old experimental results done some where else with different apparatus. Variation in the result or an alternative answer is not expected and premium is on reaching the same answer as given in the book just below the experiment.

Summing up

So where does this leave us? Science education needs to be and be changed. The principles and descriptions of what is Science and what its learning means have been articulated and classified in policy and curricular documents.

The nature of our understanding of Science, its nature and relationship with human society and natural work is evolving and changing as its relationship with the other knowledge domains including the community knowledge, yet the importance of its method and need for learning it both as a conceptual edifice and a criteria for judgement cannot be discussed or even devalued. The challenge is to make the understanding of Science, its way of thinking and doing reach a wider community in particular all those who are engaged with education in some way. Without that as a start the project of meaningful science teaching is a non-starter.

Notes of Explanations:

1. The Kothari Commission was set up to suggest the means to improve education in the country. The importance that was given to science education is evident in the fact that a task force was set up by the Commission to focus on science education. This task group focussed on science education not including medical education or professional, vocational and technical education. The later were taken care of by another task force. What the Kothari Commission says about Science education is important to consider in understanding the importance that was associated with science. It said "Science education must become an integral part of school education and ultimately some study of science should become a part of all courses in the humanities and social sciences at university stage also. The quality of science teaching must also be improved considerably so as to promote a deep understanding of basic principles, to develop problem solving and analytical skills and to promote the spirit of enquiry and experimentation."

   And "Every primary school should have a science room to keep specimens, models and charts with necessary storage facilities. Every higher primary school should be provided with one laboratory-cum-lecture room."

2. *Task Force on Science Education*: 'The mandate of the group was to focus on the science education excluding medical education and consisted of D.S. Kothari, S. Deb, B. D. Jain, P. Florence Nightingale, R.C. Paul, R.N. Rai, T.S. Sadasivan, D. Shankernarayan, Shantinarayan, A.R. Verma, R.D. Deshpande and I. C. Menon (Secretary). There was another task force on Professional, vocational and technical education. No taks force was setup for language, social studies or language education separately

3. Hoshangabad Science teaching programme was a program of Science teaching in Schools of Madhya Pradesh. For details see Joshi Sushil Jashn e Talim, Eklavya Bhopal 2015 (ibid 8)

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