Learning Curve

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A Newsletter from
Azim Premji Foundation
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Special issue on Science Education

From the Editor

Learning Curve is the newsletter from Azim Premji Foundation that we began more than five years ago, with the intention of regularly sharing information and views on key issues pertaining to education in the country. We have planned that henceforth each issue of the Learning Curve will be devoted to a central theme or issue. "Science Education" is the theme of this issue. Obviously, it is a theme where we need to cover a range of topics from 'why teach science' to 'how to make science fun for children' to 'how to encourage children to take up higher education in science' and 'how critical it is that we have a strong stream of scientists emerging from our education system'. The only way we could have attempted this was by inviting a number of practicing scientists, professors, school teachers and innovators to contribute their thoughts. Each of these eminent persons has most willingly contributed to the issue. We are greatly indebted to them.

All of us envision a dramatic change in the kind of education and learning experiences that our children receive. We want their school life to be interesting, where they can connect their class room learning with nature and life around them. The class room becomes a window to the world when there is space and encouragement for the child's spirit of active enquiry, her inquisitiveness to understand the wonders that she observes every day and, in the process, develop her analytical powers. Given this broader picture, the teaching of any subject such as science or math or geography, etc. is a means to enable the fulfillment of such educational objectives.It is in this context that we felt that we must devote the forthcoming issues of the newsletter to the teaching of science, language, social sciences, mathematics, etc. with the larger picture of educational goals and curricular objectives in mind.

I would have perhaps stopped this introductory editorial hereabouts but I have just been lucky enough to witness a couple of thrilling incidents with very young children over the past few weeks that have reinforced the relevance of the theme for this issue. The first such instance that lifted my heart was about a month back. It was 11 PM, our flight had landed three hours late, and the bus that was ferrying us to the terminal was taking its own sweet time. Adults were barely able to keep awake but there was a little girl, Simran, about 6 years old, wide awake, nose pressed to the window pane, keenly observing everything on the runway. She kept up a continuous stream of questions to her sleepy father. Sample these: "My God, such big planes, how do they fly if they are so big, they must be so heavy? I am much smaller and lighter, why cannot I fly?" A second later: "How do those small tyres not break, weighing machine *toot jaayega*!" ("...., the weighing machine will break!") And then: "How much time would they take to make such a big plane?" The father to his credit did not stop her stream of questions although he did not acknowledge any of them! The second lovely incident was about two weeks back when I saw two young children, about 7 or 8 years old, in a large wedding hall. These were the questions they threw at each other while their mother sat nearby. "See the fan above. Why does it look like one big dish when it is spinning, why cannot I count the blades?" The other child meanwhile was drawn to a person who was mopping the brown tiles nearby. He asked: "Why does the wet cloth look dark blue but the same cloth looks light blue when it is dry? But, the tile looks the same colour whether it is wet or dry! Why?"

Don't we owe all children the kind of education that will take them further and further on this exciting journey of discovery? Do write back with your views on this issue of Learning Curve which attempts to discuss precisely this question.

S. Giridhar, Head, Programs and Advocacy, Azim Premji Foundation

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Learning Science the NCF Way

Indu Prasad

The National Curriculum Framework (NCF) 2005 states that "one important human response to the wonder and awe of nature from the earliest times has been to observe the physical and biological environment carefully, look for any meaningful patterns and relations, make and use new tools to interact with nature, and build conceptual models to understand the world. This human endeavor has led to modern science."

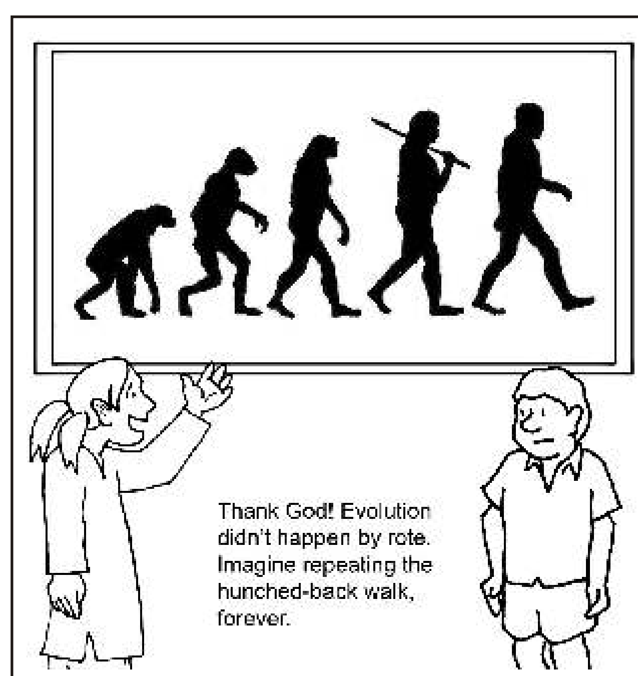
The conviction that the learning *of* science needs to be accompanied by learning *about* science is basic to a liberal approach in learning of science. Teachers of science need to know something of the history and nature of the discipline that they are teaching. Science taught from such a perspective, informed by the history and philosophy of the subject, can engender an understanding of nature, the appreciation of beauty in both nature and science, and the awareness of ethical issues unveiled by scientific knowledge and created by scientific practice.

The NCF identifies three critical issues that stand out in the complex scenario of science education in India:

- Science education is still far from achieving the goal of equity enshrined in our Constitution
- Science education, even at its best, develops competence but does not encourage inventiveness and creativity
- The overpowering examination system is basic to most, if not all, fundamental problems of science education

According to the NCF, science education should enable the learner to:

- Know the facts and principles of science and it's applications, consistent with the stage of cognitive development
- Acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge
- Develop a historical and developmental perspective of science and view science as a social enterprise
- Relate to the environment (natural environment, artifacts and people), local as well as global, and appreciate the issues at the interface of science, technology and society
- Acquire the requisite theoretical knowledge and practical technological skills to enter the world of work
- Nurture the natural curiosity, aesthetic sense and creativity in science and technology
- Imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment
- Cultivate 'scientific temper' - objectivity, critical thinking and freedom from fear and prejudice



The scientific method, as described in the NCF 2005, involves several inter-connected steps: observation, Asking questions

"Air is everywhere" is a statement that every schoolchild learns. Students may know that the earth's atmosphere consists of several gases, or that there is no air on the moon. We might be happy that they know some science. But consider this exchange in a Class IV classroom.

Teacher: Is there air in this glass?

Students (in chorus): Yes!

The teacher was not satisfied with the usual general statement, "Air is everywhere." She asked the students to apply the idea in a simple situation, and found, unexpectedly, that they had formed some "alternative conceptions".

Teacher: Now I turn the glass upside down. Is there still air in it?

Some students said "yes", others said "no", still others were undecided.

Student 1: The air came out of the glass!

Student 2: There was no air in the glass.

In Class II, the teacher put an empty glass over a burning candle and the candle went out! The students had performed an activity whose memory had remained vivid even two years later, but some of them at least had taken away an incorrect conclusion from it.

After some explanation, the teacher questioned the students further. Is there air in this closed cupboard? Is there air in the soil? In water? Inside our body? Inside our bones? Each of these questions brought up new ideas and presented an opportunity to clear some misunderstandings. This lesson was also a message to the class: do not accept statements uncritically. Ask questions. You may not find all the answers but you will learn more.

(From NCF 2005)

looking for regularities and patterns, making hypotheses, devising qualitative or mathematical models, deducing their consequences, verification or falsification of theories through observations and controlled experiments, and thus arriving at the principles, theories and laws governing the natural world. The laws of science are not supposed to be viewed as fixed eternal truths. Even the most established and universal laws of science are always to be regarded as provisional, subject to modification in the light of new observations, experiments and analyses.

Curriculum design in the NCF is in accordance with stages of learning. The focus at the primary stage is on nurturing the curiosity of the child about the world (natural environment, artifacts and people) and to develop basic cognitive skills like observation, classification and inference along with psychomotor skills through hands-on activity. It is also important for children to learn the “language” of science. The NCF recommends that science and social science continue to be integrated as 'environmental studies' with health as an important component.

At the upper primary stage, the child should be engaged in learning the principles of science through familiar experiences, working with hands to design simple technological units and modules (e.g. designing and making a working model of a windmill to lift weights), and continuing to learn more about the environment and health, including reproductive and sexual health, through activities and surveys. Scientific concepts are to be arrived at, mainly from activities and experiments. Science content, at this stage, is not to be regarded as a diluted version of secondary school science. Group activities, discussions with peers and teachers, surveys, organization of data and their display through exhibitions, etc. in schools and the neighbourhood, should be important components of pedagogy.

At the secondary stage, students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced

What Biology do Students Know?

"These students don't understand science. They come from a deprived background!" We frequently hear such opinions expressed about children from rural or tribal backgrounds. Yet, consider what these children know from everyday experience.

Janabai lives in a small hamlet in the Sahyadri hills. She helps her parents in their seasonal work of rice and *tuvar* farming. She sometimes accompanies her brother in taking the goats to graze in the bush. She has helped in bringing up her younger sister.

Nowadays, she walks 8 km every day to attend the nearest secondary school. Janabai maintains intimate links with her natural environment. She has used different plants as sources of food, medicine, fuelwood, dyes and building materials; she has observed parts of different plants used for household purposes - in religious rituals and in celebrating festivals. She recognises minute differences between trees, and notices seasonal changes based on shape, size, distribution of leaves and flowers, smells and textures. She can identify about a hundred different types of plants around her many times more than her Biology teacher can, the same teacher who believes Janabai is a poor student.

Can we help Janabai translate her rich understanding into formal concepts of Biology? Can we convince her that school Biology is not about some abstract world coded in long texts and difficult language? Rather, it is about the farm she works on, the animals she knows and takes care of, the woods that she walks through every day. Only then will she truly learn science.

(From NCF 2005)

technological modules than at the upper primary stage, and in activities on (and analyses of) issues concerning the environment and health, including reproductive and sexual health. Systematic experimentation as a tool to discover/verify theoretical principles, and working on locally significant projects involving science and technology, are important.

The NCF recommends that the curriculum load should be rationalized and the tendency to cover a large number of topics of the discipline superficially should be avoided. Both teacher empowerment and examination reform are seen by the NCF as pivotal enablers of change in the teaching and learning of science. In this regard, the document also speaks of a national testing service which could replace the current system of multiple entrance examinations.

One very interesting recommendation of the NCF is that there should be a massive expansion of activities along the lines of the Children's Science Congress, along with large-scale science and technology fairs at the national level with feeder fairs at cluster, district and state levels.

The NCF is cognizant of the fact that though all children do not become scientists or technologists when they grow up, they need to become 'scientifically literate' to better understand social, political and ethical issues, posed by contemporary society. The document also recognizes the importance of developing awareness among learners about the interface of science, technology and society, sensitizing them, especially to the issues of environment and health, and enabling them to acquire practical knowledge and skills to enter the world of work.

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Burning Questions and their Power to Kindle a Fire

Krishnan Balasubramanian

The current status of science and mathematics education is pathetic, especially in elementary to high schools. This has been caused in part by unenthusiastic teaching, which has repelled some students from these subjects, while others have been lured to more lucrative jobs, even before acquiring a university degree, such as call center jobs. Even students who may have pursued a career in science have often been turned away, either by a monotonous teaching style or by prevailing myths of alternative lucrative career paths. All of these have contributed to an alarming exodus of students from pursuing scientific and innovative research disciplines. What has gone wrong with our science and mathematics education? Is it possible to carry out cutting edge innovations in science and technology without basic foundations in science and mathematics? What can we do to keep young minds excited about scientific and technological innovations? These are indeed very complex and perplexing questions that do not have simple answers. One approach to address these questions is to simply ask what excited some scientists to pursue science and research and see how to introduce some of those excitements into the curriculum, and kindle interest in science, at a very early stage.

Many famous and accomplished scientists have often derived their inspirations to pursue research and innovations by asking a mind-boggling question, for which, until they found the answer, they could never rest. It is as if they are obsessed. This may explain the famous notion of an absent-minded professor; indeed it is not that an absent-minded professor's mind is “absent”, rather the professor's attention and brain energy are so focused on that question and the quest to find the answer to the unknown, that the professor becomes oblivious to the immediate surroundings and happenings. Science and research are, in a way, an obsession - it is a perpetual drive of enormous energy to find an answer to the unknown and until the answer is found, the obsession continues. Until we can get our students to this obsessive state of enthusiasm, it seems that we may often lose some very creative minds. Nobel Laureates Richard Feynman, Albert Einstein, C. V. Raman, S. Chandrasekhar and many others have had this thirst to understand the beauty of nature through questioning why things in nature are the way they are. Einstein is famously attributed to having said that imagination is more important than knowledge. Had Raman not asked a question as to why the sky and the sea have the same blue color on a clear day, we would not know today the Nobel-prize-winning Raman effect and Raman spectroscopy. In the same way, when Einstein questioned his teacher, who asserted that the speed of a light flashing from a moving train would be different from that of a light pulse emanating from a stationary train, his quest for a satisfactory answer to that question culminated in what is today known as the Special Theory of Relativity. This visual power to understand something in nature that we call the beauty of nature is what leads to great innovations in science. It is, therefore, extremely important to cultivate the power of imagination and the quest for answers in our students.

In trying to seek answers to what would excite a student to pursue science and research, I have asked myself the same question. I have attempted to draw some very exciting personal examples and anecdotes that attracted me to science. My very first scientific excitement was ignited by a science fair that my sister and her friends organized in Pachaiyappa's College, Chennai. I was about 13 when we went to this science exhibition where I saw a man mix two chemicals in a dark room and the whole room glowed with a luminescent blue color. The next thing I knew was that I was busy trying to understand why these two chemicals produced this beautiful luminescent blue color. On another day, when I was about 14, I saw my mother mixing turmeric water with white *choona*, (also known as *sunnambu* in Tamil; quick lime/white wash, etc. in English), and the immediate result was that the yellow-colored solution turned blood red. In many of the Hindu ceremonies, one of the traditional practices is to perform *aarathi* and the ladies prepare the *aarathi* by mixing yellow turmeric solution with the white alkaline *choona*-like substance that is predominantly composed of calcium hydroxide. Why does this yellow color of turmeric change to red? This question sparked my early interest in science, and my quest to understand this took me along a path of understanding the beauty of nature. Recently, we have tried to use a variety of household chemicals to create a kaleidoscope of colors from turmeric that are shown in Fig. 1.

Fig. 1 Turmeric in neutral solution at center surrounded by its colors in various chemicals: clockwise starting from yellow(vinegar), quick lime or choona ($Ca(OH)_2$), Ammonia, hair & grease remover, and oven cleaner.

Although the question took me on a scientific path that culminates in quantum mechanics and spectroscopy, the fact is that it was this question that resulted in a never-ending pursuit of knowledge and innovative research. In retrospect, I feel that the question was far more important than the answer itself. It is the question and that never-ending quest, or what one may call an obsession to find the answer, which lured me to science and scientific research. Asking fundamental questions, no matter how simple or how complex they may be, is the most critical path to innovation.

My mother was making *Mysore pak* one day and *rosagulla* on another day, and I saw how milk was getting separated into a solid state when she added lemon juice to milk. Why is it that milk separates into two distinct phases of solid and liquid upon the addition of lime juice? Here again, asking a question was the key to my pursuit of science. Is it the acid in lime that is responsible for this or is some other substance the cause? What is really the state of milk? Questions like this can take one on the path of understanding hydrogen bonding and structures of proteins, but it is important to ask questions, whether or not the answers are obvious. Likewise, I often asked: "Why is it that most substances turn from solid into liquid when you heat them, but egg yolk turns into a solid from a liquid state when you boil it?" Again the answer, that it is caused by the breaking of the hydrogen bonds, resulting in denatured state of proteins in egg yolk, is not as critical as the question itself. The question was what engaged and attracted me to science. While making a number of sweets, often solid sugar is mixed with water and heated, to bring the solution to different states, either a "string state (*kambi paagu* in Tamil)" or a "spherical state (*urundai paagu*)", depending on which kind of dessert is being made. If one asked questions based on these observations and the different states of the solution thereof, one would travel to the world of states of matter and phase diagrams! There is so much that happens around us, that we often take for granted or never have the opportunity to stop and wonder about.

My interest in science was further fueled by more questions that I asked. This often challenged my school teachers, as they started finding me intimidating because of the perplexing questions that I asked. In one of the chemistry classes, I was asked to balance a chemical equation, which is tantamount to placing coefficients in front of the chemicals so that the total number of different atoms is the same, on both sides of the reaction. For a somewhat complicated reaction, I arrived at two different solutions, such that one is not a multiple of the other. For those who are eager to know the reaction, it was a reaction between $KClO_4$ and HCl. The trouble is that we were taught that there is a unique solution to balance a chemical reaction, or otherwise reactants will not react in definite proportions. Yet, my question to the teacher was, which one of the two solutions is then correct? He was baffled and did not provide me with a satisfactory answer to my question. So my quest continued. When I went on to Birla Institute of Technology and Science (BITS), Pilani, I continued to ask the same question to some of my chemistry teachers, but could not get satisfactory answers. It was not until I took a course in linear algebra and matrix theory that I was able to come up with a satisfactory answer to my quest on balancing chemical reactions. From linear algebra's rank-nullity theorem, I could indeed establish that for the $KClO_4$ + HCl reaction there are not merely 2 independent solutions but infinite solutions. Indeed it turned out that more chemical information, such as from chemical thermodynamics, is needed to isolate the correct solution or split the reaction. The trouble with our education is that teachers often segregate their knowledge and understanding to narrow disciplines, when in fact, the majority of the real world problems are inter-disciplinary. The questions pertaining to nature do not have the power to know if they are mathematical, chemical or biological! For example, flower petal patterns and cactus thorns are arranged in mathematical sequences called Fibonacci numbers, where one finds harmony of mathematics, biology and nature's way of space optimization. This results in Fibonacci patterns. It seems that as a teacher, one often needs to develop an understanding of multi-disciplinary concepts, rather than segregating knowledge into a given discipline.

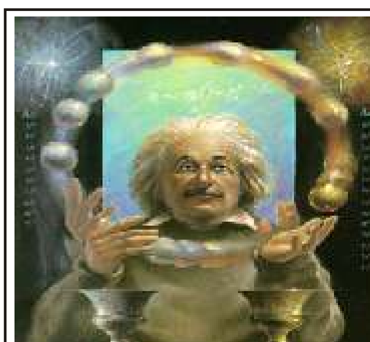
When I was a student at BITS, Pilani, the then Director of the Institute, Dr. C. R. Mitra, asked me and my classmate, Subhash Gupta, to take up the challenge of developing and teaching a course on "Concepts in Science", to all incoming freshmen students. (A few pages of this book may be accessed through the link: http://www.mcs.csuhayward.edu/~kbalasub/reprints/1.pdf). This was indeed a great innovation in teaching, for me, as it provided an opportunity to experience the joy of teaching while I was still a third year student at BITS. We designed the course based on an innovative method of learning concepts by asking questions and subsequently, seeking answers to them. Although this style was particularly challenging for the teacher, it had considerable merit. As part of the course, each student was asked to come up with a science project which was simply to "stop and stare" at something around and explain the observation using the concepts of science. One exciting project was related to an observation of trees on the side path of Vyas Bhawan hostel at BITS. The project was on explaining why trees along the side path, at times, oozed out fluid under high pressure, through the bark openings. The explanation drew concepts from capillary action to hydrodynamics; but once again, it was simply the question that was important. The question may take the person on any path; it could be simple capillary action to more sophisticated hydrodynamic equations, but it is the question that leads to knowledge and excitement. Sanjib R. Mishra, a student in my class, simply asked the question: Why does a stream of water, passing through a wash basin sink, create a type of turbulent current, especially when the last bit of water passes through the sink? This question led Sanjib to the path of fluid dynamics and Navier-Stokes equation, at an early stage and as a freshman student. Most importantly, the course and the experiment kindled a spark of excitement for science in Sanjib, which culminated in his obtaining a Ph.D. from Columbia University and finally, a professorship in Physics at Harvard University, researching in high energy Physics. This course fascinated Sanjib and another student, Rattan Nath, so much that we jointly taught the course again, when I was in my fourth year at BITS. This resulted in us bringing out a 700-page book titled, "Concepts in Science". In a sense, our obsession was never-ending and we put in enormous time and effort to writing this book, without feeling any pain whatsoever. While I was a National Science Talent summer student at Indian Institute of Chemical

Technology (IICT), Hyderabad, my friends and I were walking around the campus of Osmania University and were intrigued by the seeds that had fallen from a tree on the campus. The seed had a hard shell that looked like the shell of almond seeds, but we were warned by the local people that the seed was not edible. Intrigued by the questions that I asked about the seed, my summer project at IICT was on the extraction and analysis of the oil extracted from the seed, which I subsequently learned was *Pongammia Pinata*, commonly called the *pongu* seed. Again, it is this question on the seed that took me to a new area of research on natural product chemistry, chemical extraction and spectroscopic analysis of the oil, using a variety of techniques. It turns out that the oil has a number of medicinal properties and is used in herbal medicine. My quest for answers to a particular question often led me to different disciplines from mathematics to physics to chemistry to biology and thus, not restricting me to segregate my understanding to one discipline alone. My interest in learning the connection between mathematics and chemical isomerism resulted in me carrying out my master's thesis with Professor V. Krishnamurthy, a mathematician by training, although I belonged to the department of chemistry.

Life histories of many famous scientists and mathematicians clearly point to a unifying theme that science evolved by asking questions and the subsequent obsession to finding answers to those questions. Teachers should try to inculcate this culture into their teaching style and the curriculum, and encourage students to actively participate in the fundamental quest for answers to the unknown. It is equally important that a number of practical and interesting demonstrations of scientific principles are included in teaching. It makes it far more interesting to point out the various applications, relationships, and reasons as to why we are learning something, at the very outset, as opposed to introducing text book material without providing adequate motivation to understand the same. For example, sequences of numbers, like arithmetic progression, geometric progression, or Fibonacci sequences can be introduced with motivating and anecdotal examples, such as how Gauss discovered the technique of finding the sum of natural numbers when he was merely in elementary school. The story goes that an elementary school teacher asked the students to add the first 100 numbers, hoping that the task would keep the students busy for quite some time. But Gauss came up with an answer very quickly by discovering that if he wrote the same numbers in the reverse order below the numbers, the sum of each column becomes the same (as shown below), thus finding the answer instantaneously.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	...	99	100
	100	99	98	97	96	95	94	93	92	91	90	89	88	87	....	2	1
Total	101	101	101	101	101	101	101	101	101	101	101	101	101	101	....	101	101

We can make science really exciting by visual demonstrations, anecdotes, historical perspectives, applications, and by simply asking questions and seeking answers. Indeed, asking a question turns out to be far more important than the answer itself, as the path of seeking answers to these riddles introduces students to the fun of experimenting with science.



"Eternal Mystery of this Universe is its Comprehensibility"

- Albert Einstein

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Developing Scientific Temper

Dileep Ranjekar

Among the several goals of education, the one that appeals to me the most is "Developing Scientific Temper". There could be several reasons for this - upbringing, the education that I received, the atmosphere at home and the fact that both my brother and sister are scientists of some repute, or could be the work environment in the organisation I worked in.

Watching my ten-month old grandson, Anurag, grow, and my recently spending a day at the "Science Mela" in Shorapur block in Karnataka, are two experiences that have made me think of this subject more seriously.

For Anurag, it is a whole new world. He has just learnt to walk independently, stand up, reach out, touch, put pressure on things, and before him lies a whole new world to be explored. It is absolutely amazing how he keeps repeating things tirelessly, saves his fingers from getting crushed, does not waste time in crying even if he falls quite badly, learns how to move knobs, understands what will start music and what will stop it, interestingly keeps shifting his attention to something new, and shows immense joy on his face when he causes the light to switch on or off, or the moment he encounters any new attraction. There are no pre-conceived notions, no *one* way of doing things, no resistance to absorb fresh facts that emerge out of a new experience.

The "Science Mela" in Shorapur was a different experience. It had the ingenuity of primary school children and their teachers in organizing several kinds of experiences for the 1500 children and their parents who participated in the "mela". It broke several commonplace myths and created fresh awareness about one's own existing knowledge and understanding. I, for one, had a notion that I had a very good sense of accurately judging weights. In one of the stalls, I was required to lift three different stones and guess the weight of the stones. I was crestfallen to know that all my guesses were nowhere near the actual weight of the stones. The science mela was a powerful example of how, by simple methods, awareness, interest and knowledge could be created at a mass scale through an event that is organized by the children and the teachers themselves. What appealed to me, was the difference the mela would create to the life of those children and teachers who organized it.

Scientific temper has been defined by several educationists, philosophers and scientists. Our Indian Constitution upholds the cultivation of scientific temper as one of the fundamental duties of citizens. Scientific temper is an attitude or a way of being that involves application of the mind, application of logical analysis, willingness to meet with new facts and evidence without pre-conceived notions, and willingness to question conclusions based on newer evidence. What does this entail or lead to? Necessarily an open mind, the ability to consider facts as they exist, discuss, debate, develop rationale, argue, analyse before concluding, and the willingness to live with the co-existence of several truths.

> *"Science is a way of thinking much more than it is a body of knowledge."*
>
> *- Carl Sagan*

Even to an untrained mind, science automatically means knowledge, experiment, questioning, gathering of data, reason, something that is not mystical but can be proven, touched, felt, smelt, experienced, etc. Scientific temper would mean comfort with all the above and more. Very rightly, the distinction has often been made between "science" and "scientific temper". While science gives us knowledge, tells us the logic, provides an experience, explains why things exist the way they do, "scientific temper" would guide us on the constructive use of the knowledge, abilities and experiences that science equips us with. There is both wisdom and morality involved in the usage of knowledge. Thus, for instance, scientific temper would lead to an attitude of "secularism" where you respect others' religious practices, rather than developing blind faith in a single religious practice and propagating that it is the only "right" way to practice religion.

There is no place for "superstition" and "blind faith in mythology" in the world of scientific temper. While mythological stories could be powerfully used to lead to virtual learning for young minds, forcing people to believe in stories that have no evidence is counterproductive to the process of forming a logical society. This can also be extended to learning history where one has to seek evidence, examine the same, connect to several other frames and conclude reliably as to what would have happened during a certain period rather than resorting to ambiguous interpretations based on one's own belief of what must have happened.

I would go the extent of saying that scientific temper has greater implications for the broader way in which society and human beings think, respond, and conduct themselves, than its implications for science itself. A doctor, for instance, may be a great scientist but cannot be considered as having scientific temper if he/she does not meet patients on time and extorts disproportionate money for the treatment offered.

It beats me when I hear reputed science education institutions having politics based on caste, gender and several other illogical issues. One may recollect the two suicides not too long ago, at one of the leading institutes in the country - one for harassment, based on social backwardness and the other arising out of stress due to the unmarried status of the lecturer, where the parents were forcing marriage. These are reflective of the need for the development of a "scientific temper" in society at large. How do we, in the twenty-first century still discriminate based on caste, creed, religion, gender, marital status and economic status of a person? Why don't we accept that marriage is a personal choice and that standard norms for a 'marriageable age" should not have any place in current modern society? Scientific temper plays a major role in questioning status quo, breaking stereotypes and establishing practices that meet the current needs of society.

To me, scientific temper is accepting newer methods of thinking, continuous questioning, being open to accepting that your own experiences, views, and conclusions need continuous re-calibration, and breaking stereotypes. It is about our ability to say "I don't know". A truly scientific attitude should make us tolerant, break artificial barriers of caste, religion, political and geographical boundaries, and enable us to be self-reliant to the extent that we have the courage to change ourselves at any phase in life.

Dileep Ranjekar is Chief Executive Officer, Azim Premji Foundation.

I asked

"Although I have asked you many a thing,
Dear sphinx, my mind is still spinning
With many more questions I would like to ask,
Do you think you would find it too big a task?

'My child,' the sphinx said, 'I will certainly try
To help you understand the reasons why
The things you ask keep happening,
But for that we will have another meeting.

'Until then, however, remember one thing,
It is more important to be questioning,
Than it is to know the answer why
Things happen as they do, but try!'

An extract from the book, "I Wonder Why" (ISBN 81-7011-937-5), Pg. 88, authored by Neeraja Raghavan, and published by Children's Book Trust, New Delhi.

Our Genes tell us We are All the Same

I would like to think that the ape and I
Are more different than alike: you know why!
But a study of both our genes unravelled
That from the ape, we've hardly travelled!

What's more, between you and me,
There's far less difference than what you see,
You may be tall and I may be stout,
And we may think that's enough to find us out.

If your God and mine are not the same,
We think it right to call His name,
And fight each other: even blood we shed!
We feel so different: from toe to head!

Yet these four letters, A,T, G and C
Are lined up more or less similarly
In fact, they are so neatly arranged
As to differ in bits: now isn't that strange?

So all of us are pretty much the same,
We may differ in looks, and even in name,
Just like those forms of energy bright,
We differ only in form: now, isn't that right?

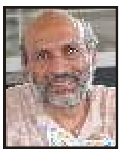
If only we could all keep this in mind
I am sure that pretty soon we'll find
That we can sometimes disagree,
But we can still live harmoniously!

Just as those packets of energy change,
Forms and names: they do exchange,
We, too, can shake each other's hands,
And tie together many different lands.

- Neeraja Raghavan

Making Things, Doing Things

Arvind Gupta



Good science need not be expensive. It can also be great fun.

The best Indian book on primary science, Preparation for Science, dates back to 1928. It was written by Richard Greggs - an American economist who was deeply inspired by Mahatma Gandhi. For two years Greggs taught activity-based science in a school in Himachal Pradesh run by the American missionary, S. E. Stokes. This remains the most pioneering treatise on how science should be taught to children in Indian schools.

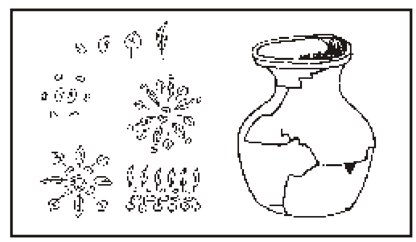
Greggs wrote:

"The apparatus required is exceedingly simple and inexpensive, and almost all of it is familiar to village children. Most of it can be made by village carpenters, potters or blacksmiths. The children must not get an idea that science is machinery or strange technology. The great pioneers of science did their work with very simple apparatus. It is possible, therefore, to follow their footsteps and learn to do scientific thinking without much expensive or elaborate apparatus. After all, the student's mind is the most expensive piece of apparatus involved."

Greggs further commented, "I do not want Indian children in villages to get the idea that science is only a school affair or only relates to shiny brass and glass devices and paraphernalia. I believe they can learn to think more clearly and to acquire a scientific attitude without all the expensive and complicated apparatus used in western laboratories, or at least with extremely little of it."

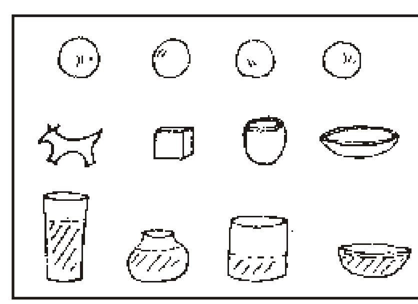
As has often happened in the history of science, this prophetic book remained buried until Keith Warren, a UNICEF consultant, rediscovered it in 1975, illustrated parts of it, and brought it out as 'Preparation for Understanding'. It helps children to discover an order in the world around them. They seek out patterns using pebbles, twigs, leaves, wire, seeds and other natural materials - stuff which does not cost much at all. If children don't have paper / pencil, they draw patterns on the ground with a stick.

Children arrange leaves and seeds to make several *"rangoli"* like patterns.



Children are asked to piece together a broken earthen pot with wet clay, akin to solving a 3-D jigsaw-puzzle.

In another exercise, a child takes four similar balls of clay. S/he then moulds each into a different shaped animal, a cube, a pot and a plate. The child is then asked: Which one is heavier? Does the shape change the weight?



Children pour out the same cupful of water in four different containers. Then they are asked, "Which vessel contains more water?"

The basic tenet of the book is : Before children can understand a thing, they need experience: seeing, touching, hearing, tasting, smelling, choosing, arranging, putting things together and taking things apart. Children need to experiment with real things.

The best Indian effort to revitalize school science education was certainly the Hoshangabad Science Teaching Programme (HSTP). Started in 1972, the HSTP eventually spread to over 1000 government middle schools in 14 districts of Madhya Pradesh. It was based on the discovery method - children performed simple experiments and then answered questions based on what they did. They were not “passive consumers” but “real constructors” of knowledge. There were no text-books, only workbooks. The programme involved the active participation of teachers in designing the curriculum. It attracted many passionate and competent people. Prof. Yashpal came as the first teacher trainer. It unleashed tremendous energy and creativity. The task was not just to replace standard flasks with local glass bottles. The search was for local substitutes, low-cost, non-alienating materials, close to the cultural milieu of the child. This required an open mind and a critical outlook. Children dispensed “dissecting needles” in favour of “babool” thorns. Phenolphthalein - an indicator used for titration - was discovered in the well known brand of laxative “Vaculax”. The tablet was mixed in a known quantity of water to make a wonderful “indicator”.

The Second World War devastated many nations. Faced with severe economic hardships, some poor countries managed to build schools. But then they had little money left for setting up science laboratories, which were expensive to build. In the late 1950s, J. P. Stephenson, a British teacher, put together a book showing possibilities of doing process-based science using very simple materials. The title of the book was itself significant: Suggestions for Science Teachers in Devastated Countries. This book took the world by storm. It showed that expensive, fancy equipment were far removed from the lives of ordinary children - in fact very alienating. UNESCO agreed to widen and deepen the scope of the book and thus came out the famous UNESCO Source Book for Science Teaching, the Bible for science activities. In 1963, this book was translated into Hindi, Marathi and a few other regional languages.

The UNESCO Source Book for Science in the Primary School, authored by Winnie Harlen and Jos Elstgeest, was first published in the early 1990s. Its international edition was priced at US $20. Fortunately, the National Book Trust reprinted a low-cost Indian edition of this wonderful book priced at just Rs 65. This book has never been reviewed but it is still in the fourth reprint. This reposes my faith in ordinary teachers - a good book, reasonably priced, will sell well. The book has two parts: a theoretical section followed by four amazing science activity sections - Children and Water, Children and Balances, Children, Mirrors & Reflections and Children and the Environment. If only some visionaries would translate these activity books into local languages?

Experience the world over has shown that pre-packaged science kits seldom work. In most cases they lie unopened. The teacher did not think of them, design them, assemble them and so s(he) is not confident to use them. The kit could break when used. So it is best kept locked up. But whenever teachers have been shown possibilities of making simple science models using everyday materials they have shown great enthusiasm. When they make things with their own hands they feel “empowered” and are more likely to use them in practice.

We live in a consumerist society which produces mountains of junk - cardboard cartons, ball pen refills, old pens, coins, broomsticks, newspapers, cycle tubes, matchboxes, tetrapaks, milk bags, ice-cream sticks, straws, etc. The list is endless. All this stuff can be recycled back into joyous science models and toys for children. For instance, primary school children could make a wonderful hand pump with two film cans joined by a length of old cycle tube with flaps of sticky tape for “valves”. This inexpensive pump can inflate a balloon and throw water 10 feet away!

Children understand best when they see a science principle incorporated in a toy. If they can play with it, then they get a better “feel” for it. “Centrifugal” and “centripetal” forces are abstract words and mean little to children. But a broomstick “spinner” can lend meaning to these words. A self-made toy acrobat which flays its hands and legs when spun can concretize this concept. A hundred such wonderful science toys have been collated in a book titled, The Joy of Making Indian Toys, by Sudarshan Khanna (published by the NBT and costing Rs. 40 only). These toys have been there since ages. Every generation has enlarged this repertoire and left them behind in the public domain. These toys, made from 'throw away' stuff, are eco-friendly and the poorest children can enjoy them. In sculpting them, children learn to cut, trim, glue, fix, nail and assemble together a variety of materials. They also learn great science.

The crisis of science is that people still do not want to dirty their hands. Rote learning, the chalk-and-talk method still reigns supreme. Everyone is out to "cover" the course, forgetting that the whole task of education is to "uncover" things.

Ann Sayre Wiseman, creative director of the Children's Museum in Boston and the author of the landmark book, 'Making Things', summed up the essence of good science in these words:

It's OK to fail.

It's OK to make mistakes.
You will learn a lot from them.

It's OK to take risks.
It's OK to take your time.

It's OK to find your own pace.
It's OK to try it your own way.

It's Ok to fail.
You can always try again free of fear.

It's OK to look foolish.
It's OK to be different.

It's OK to wait until you are ready.
It's OK to experiment (in safety).

It's OK to question the "shoulds".
It's special to be you.

It is necessary to make a mess
Which you are willing to clean up.
(The act of creation is often messy)

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Listening to Children's Voices in the Science Classroom

Jyotsna Vijapurkar

A large body of research in science education has demonstrated that children have alternative concepts quite different from what is taught in the science class. Most often, the exercise of teaching changes children's ideas from one incorrect concept to a modified, but still incorrect one. The good news is that teaching does help bring about a concept change; the bad news is that often it is not quite what the teacher had in mind!

The very fact that researchers have uncovered so many alternative concepts that children hold, despite instruction, indicates that someone, somewhere was listening to what children had to say. Surely a clue of this kind would have had to be the starting point, the motivation, for further investigations.

Time and again, however, while working with teachers, it has emerged that a lot of children's ideas and theories come as a complete surprise to them. I have been struck by how large a number of teachers seem unaware of what is going on in the child's mind. Why is it that even after teaching for years, the realization that there is a disconnect between what is taught and what is learned continues to elude us?

The answer, I am convinced, lies in how our science classes are conducted.

In a typical classroom, when the teacher poses a question, one or two hands go up, one child gives the expected answer, is acknowledged, and the class moves on. Often the question asked has a 'correct', or rather "the" correct answer from the textbook. In some rare instances, the answer may have to be original. Even here, children quickly figure out what the expected - the single 'correct' - answer is. They will please the teacher by giving this answer. Life in school has, for the child, always been about pleasing, or at least satisfying, the teacher. Kids are smart. Even if the questions are not leading, they can get their cues from the teacher's intonation, body language and expression in arriving at the expected answer.

Here is a snapshot of one classroom interaction that I recall from years ago while working with children of Class V. I asked if anyone had seen a sun bird.

“Yes,” said many, raising their hands.
“What colour is it?” I asked.

“Yellow.” (lucky guess!! “Sun” bird must be yellow).
“OK, how big is it?”

Several children started to show me with their hands, palms facing each other and separated, to indicate the size. As they closely scrutinized my facial expression for some cue, the palms went slowly closer, then slowly spread apart. I consciously maintained a poker face, so they had no idea where to stop! They got found out!

A common scene in such classes is that when children speak (generally just one or two - the class toppers), only the teacher listens; the other children probably pay no attention to the answer. If they do - and even if it conflicts with what they think - no one speaks up. This is the classroom culture that children have adapted to. All of us who have interacted with kids outside the classroom - our own children, or a neighbor's/friend's children - know how much they talk, and how they ask difficult and original questions. Parents will often proudly show this off. How unnatural it is, then, that they should suppress this natural curiosity in the science classroom!

Contrast this with a class where everyone listens to what is being said, and responds to it; a class where every child is not merely allowed, but actively encouraged to speak. This is particularly needed with the shy ones in the class. In a class full of children, some are bound to be shy, some disinterested, some aggressively seeking the teacher's attention.

It is up to the teachers to set this culture in the classroom. The techniques to do this, once laid out, seem easy, even trivial, and therein lies their strength.

Many who hesitate to speak in front of a large group in a formal setting may do so from fear of ridicule. A rule that no one laughs at anyone's answer or question has worked very well for us. Of course this is hard to enforce, given how spontaneous laughter is; but just saying something nice to the child for bringing that point up - common civilities we engage in among peers - quickly changes the situation.

The disinterested ones, having figured out that they will be heard, and seriously, do get interested. It is important also to make it clear from the outset that when the teacher or any student has something to say, the others will listen, and respond if they wish. Unless one strives to implement this, most children in our classes tend to ignore what other students say. The dialogue, if any, ends up usually as a teacher-student one; once this rule is implemented, student-student dialogue occurs freely, moderated by the teacher (to keep the focus on the topic at hand).

Once it is conveyed right at the start that the teacher expects every child to speak up, and fully intends to give every child a chance to do so, the aggressive attention seekers tone down. They are not to be discouraged to speak, but given the same chance as others.

Of course, it may not be possible to have every single child speak in every single class. Over a period of time, say several days, it has been our experience that children open up. Sometimes, when there are opposing viewpoints, I ask for a show of hands to indicate which one they agree with. And it is okay if some do not raise their hands at all - in our classes they have learned that it is okay to not be sure. Ask the natural next question - 'how can we find out?' - and we have a real science exercise in the classroom!

When there are no negative consequences for saying something, the real exploration of ideas begins. Sometimes, a really bright child gives a most wonderful answer, with all the 'ifs' and 'buts' covered. Tempting though it is, the teacher would do best to not acknowledge it as such right away - until the rest of the class is asked what they think. Otherwise no one is motivated to seek an answer of their own. And of course one should acknowledge the first answer after all have had their say.

In such a classroom environment, the teacher knows what children think. Why is it important for the teacher to know this? After all, curricula are designed, textbooks written and prescribed by someone else, often someone far removed from the actual teaching. But that is precisely why teachers, who are the last and most vital link in this long chain, should be aware of what worked and what failed. Who is better placed than a teacher to give feedback to the 'system'?

> *"Just because something doesn't do what you planned it to do doesn't mean its useless."*
> *- Thomas A. Edison*

This culture of the classroom reaps rewards far, far greater than just the discovery of what children's alternative ideas are. Children get truly actively engaged in the class. They know their ideas matter. They learn to resolve cognitive conflicts, to critically evaluate others' and their own answers.

And thus begins their journey towards the wonderful exploration of the world that is science.

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From the real to the abstract

G.S. Jayadeva

I do not actually hate mathematics, but for a long time I believed that I hated the subject because of various reasons. The strongest reason was the very process in which maths was taught. Especially, the tyrant teacher and his stick made maths the most formidable subject. In retrospect, nearly forty years later, I understand that I certainly was capable of learning mathematics quite well. It was my bad luck that every other incident during my school days made me believe that I could never learn maths, including the deep sympathy shown by all my well-wishers.

What went wrong? The answer to that is actually quite simple. The numbers never represented any tangible object of perception, but were mere signs that floated in a lifeless void like disentangled pieces of a complex puzzle. There was no reason why they had to be put together, and even if they were, were as lifeless as before.

Being an ardent student of science, I realized the importance of maths later in my college days, but it was too late. If this would have been taught to me as something related to my day-to-day life experience, I probably would have learnt it.

With this experience in my mind, we are now trying to make maths a true learning experience of immense joy and fun for children in Deenabandhu school, Chamarajanagara. Lessons of maths are given in a guise of biology that offers vivid experience.

Different types of dicot seeds are planted in a glass jar so that children can observe the growth of roots and shoots simultaneously. Seeds of beans, peas, green gram, etc. are planted. Every day, children measure (and keep a record of) the growth of roots and shoots. It is interesting to observe that the roots of some pulses grow much faster than their own shoot in the beginning, while, in about a week's time, the shoots overtake roots.

This process of observation and recording gives children an opportunity to learn the skill of measurement and of recording data accurately. They also learn to recognize patterns in a biological phenomenon and hence learn to predict results in a similar situation. Apart from this, we could draw a vital link to maths through this biology experiment. The growth of the roots and shoots, recorded as centimeters, are no doubt numbers. Yet these are not lifeless numbers, but represent a live phenomenon. Using these data, children developed a bar graph and a line graph. These graphs paved the way for a very active discussion among the children. There were no ready answers for many questions and we learnt that science is not always about the answers, but can also be built around questions that cannot be answered instantly in a classroom situation.

There was a question about the bar graph and the line graph. If a bar graph explains everything, why do we need a line graph? Children were allowed to discover it by themselves. One of them quickly recognized that while the bar graph gives an over all picture of the phenomenon, the line graph could throw light on variations that occurred during the period of observation. Thus, it was inferred that the curve graph reflected the *process* rather than just the *end result*.

Needless to say, the numbers in this experiment represented an unforgettable phenomenon. Hence, these 'living numbers' could be harnessed for more mathematical understanding. The same numbers were used to learn ratio. Ratio of the growth of roots and shoots could be derived from these numbers; here again, the meaning of the ratio comes in relation to a phenomenon and it is not just a play of lifeless numbers.

> *"A scientist in his laboratory is not only a technician. He is also a child placed before natural phenomena which impress him like a fairy tale."*
> *- Marie Curie*

Similar experiments were conducted to understand the concept of ratio. For example, children undertook an exercise of measurement of the length of the head and the body, of children of different age groups. The length of the head attains its maximum very early , say by six or eight years. However the body elongates until the age of 18 years. Even the school teachers were measured for the length of their head and body! In this experiment also, the numbers were not lifeless. At the same time, we debated as to why the head has developed to its maximum size at such an early age. How many neurons are there at birth? Do neurons increase in the life time of an individual?

This kind of scientific understanding of mathematics, at the primary school level, provides children a sound foundation to better understand higher, more complicated and abstract, mathematics and science at the later stages of their education.

G.S. Jayadeva founded the Deenabandhu Trust (http://www.deenabandhutrust.org) in 1992. They are presently working in association with the National Institute for Advanced Studies for improvement of primary education in Chamarajanagar district of Karnataka. He can be contacted at gsjaydev@rediffmail.com

Bringing the Laboratory into the Classroom: Bringing Inventive Thinking into the Mind

Neeraja Raghavan

There is no doubt that a good laboratory will enrich the learning and teaching of science.

While this is undisputable, it is possible to transform the teaching and learning of science even without a full-fledged laboratory, provided one can draw upon everyday experiences, commonly asked questions, easily available materials and just a few tools that may need to be purchased.

If we map the journey of a typical science class, we will probably see something like what is shown below:

1. Teacher first reads through the syllabus
↓
2. Teacher reads the relevant portion of the text
↓
3. Teacher plans the lesson(s) to cover that particular topic
↓
4. Teacher covers the topic in the allotted number of periods
↓
5. Teacher gives worksheets and/or a test to assess learning levels

In the above work flow, the role of the teacher is that of a lecturer, and (s)he will doubtless cover the topic efficiently, if (s)he moves as planned. The role of the child is largely that of a passive recipient, who is called upon to listen to and absorb whatever was taught, only to repeat it (preferably verbatim) during the assessment. Conspicuous by their absence are the following: experiential learning, the triggering of curiosity, the articulation of questions, the performing of experiments, the noting down of observations, the 'seeing' of a pattern in data collected, the drawing of logically consistent conclusions and finally, the shift in thinking that results from a transformative experience.

In order to show that none of these processes is too far - fetched - even in Class IV - in a school without a laboratory, I shall first draw upon a research paper which describes a very simple experiment. A fourth grade teacher had to teach 'heat' to her students, and she chose not to adopt a route such as the one delineated above. Instead, she began by asking the nine-year-old children (in cold Massachusetts) about their experience of warmth and heat, in the nine winters that they had faced so far. (See text box below)

"Sweaters are hot," said Katie.

"If you put a thermometer inside a hat, would it ever get hot! Ninety degrees, maybe," said Neil.

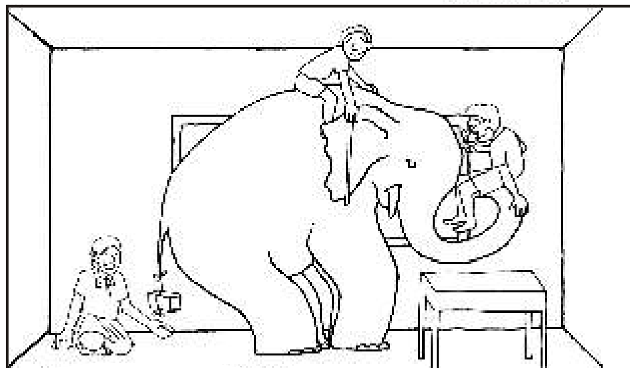
"Leave it there a long time, and it might get to a hundred. Or 200," Christian added.

Confronted with the children's preconceptions in so direct a manner, this talented teacher decided to have the class test out each one of them. She did this by having the class place thermometers in hats, sweaters and even a rolled up rug. When children found that the first few readings on the temperatures did not show any difference, they were convinced that they needed to leave the thermometers in longer. (Here, the resistance that we normally encounter in giving up a pet premise is palpable!) So they left the thermometers overnight and came back the next day, sure that the temperatures would be soaring! Instead they found no demonstrable change. Still, they were not yet ready to abandon their ideas. A less talented (or more harried) teacher would probably have stopped at this point, corrected them and explained the reason why the temperature did not rise. Instead, this teacher empowered her students to 'own the problem' and continue pondering, testing and discussing their ideas until they were themselves ready to give up their erroneous belief and incorporate new knowledge.

What is remarkable about this class? First, the teacher was less focused on covering the syllabus than on uncovering students' preconceptions. Next, she was wise enough to allow the learning to unfold at its own pace, by testing the premise of each child, and waiting for them to give up their incorrect preconceptions only when they were convinced of their incorrectness. I can almost hear the teacher's lament: “But we can't possibly do this for each and every topic! We will never finish the syllabus in this way!” Yes, you probably won't. But to your surprise, you may find that you won't need to. Because in the process of nudging the children to think through their own preconceptions, the immense learning that has been effected will stand the class in good stead when the next topic has to be DIScovered! (not covered.) [Besides, by covering the entire syllabus under the thick hood of efficient transaction, one is not effecting a change in thinking at all: and how, then, can one claim to be teaching science?] Thirdly, the link between scientific thinking and one's everyday life are so obvious in this class, that there is no need to teach that chapter on 'Scientific Temper' (which usually forms a mandatory part of the syllabus) and now, doesn't that reduce the 'portion' to be 'covered'?!

Science Communicator's Forum (SCF) has innovated cost-effective ways to convey scientific concepts. For instance, since prisms are expensive, members of SCF use a glass of water and an inexpensive laser light to demonstrate the internal reflection of light. Similarly, in order to explain the concept of land and sea breeze, students are asked to take a tumbler and put some water on one side and sand on the other side. The tumbler is then left outside in the sun. An incense stick is lit and placed in between the sand and water. Once the sand and the water are warm, the movement of the smoke indicates which way the breeze is blowing. This way, students get to learn the basics of how sea and land breeze occur. [from http://timesofindia.indiatimes.com/Education/Beyond_the_chalk talk_method_of_teaching/articleshow/3935253.cms Times of India 5 January 2009, Beyond the chalk-talk method of teaching)

It is important to see how the shift in thinking can only occur when the teacher begins to view science more and more as a 'Verb', and less and less, as a 'Noun'. In getting children to 'own' their premises, one is empowering them to hold certain beliefs, something we never do when we are only focused on 'covering' the syllabus. Then, as we lead the children into enquiring into these strongly held beliefs, we are moving from a secure ground where the child is not threatened: instead, the child is confident enough to test his/her premise. Would it now be unreasonable to expect such a child to carry on with this practice of testing out dearly held beliefs, even outside the classroom? Surely not! It is, therefore, desirable to bring in this process of thinking into the science class, and much of this does not require a hi-fi laboratory, at least for Class IV and V.



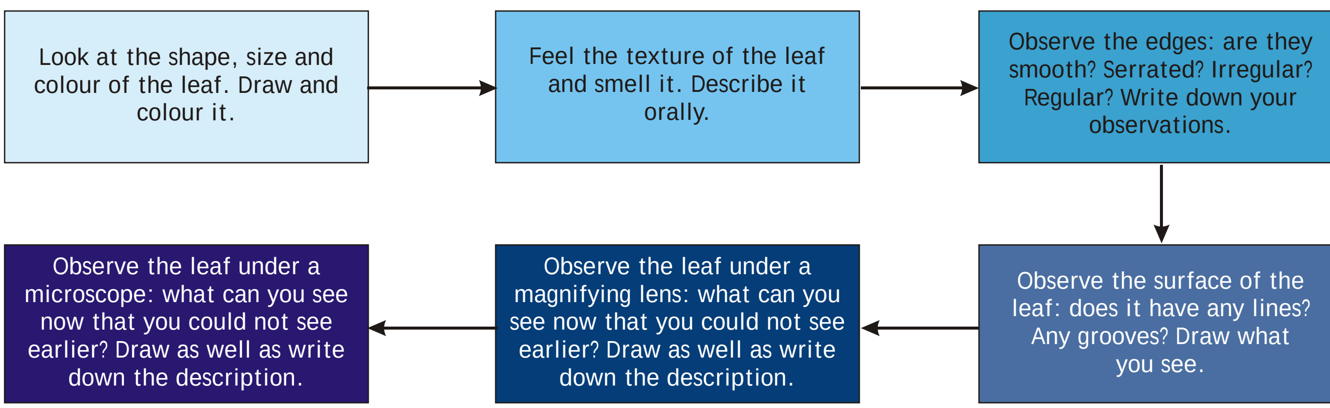
Classroom lab-to remember science like an elephant's memory.

Some suggested ways of developing Observation, Enquiry and Thinking Skills in Class IV and V are described in the following section, through the example of a *Leaf*.

In addition, it is important that the teacher goes to class prepared with at least a few names and biographies of scientists who have worked on the topic to be taught (in this example, leaves and plants) so as to be able to connect at least some of the questions asked (by the children) to those asked by scientists down the ages. Beginning with a set of stories about scientists, (to be culled from references, some of which are suggested elsewhere in this issue), the teacher must show how those scientists looked at certain things and then asked certain questions, just like the children are now doing in class. [For example, in connection to some of the questions posed for a *leaf*, here are some related scientists and discoveries, which took this writer less than ten minutes to cull from the Internet:

- While studying an orchid, botanist Robert Brown (1831) identified a structure within the cells that he termed the "nucleus."
- In the 1770s, Jan Ingenhousz discovered that plants react to sunlight differently than shade and from the underpinnings of this, the understanding of photosynthesis was born.
- From the fifteenth century onwards, early European explorers who went on sailing expeditions around the world, noticed that the tropics host a much greater variety of species. Answering why this is the case allows today's scientists to help protect life on Earth.]

Guidelines for *gradually* honing observation skills: (increasing intensity of colour of textbox shows increased intensity of observation) We are taking the example of a *leaf*:



Guidelines for *gradually* honing enquiry skills : In the example of a *leaf,* the nature of questions that can be drawn out/discussed could be of the type:

- Why is this leaf shaped thus?
- What are the uses of this leaf?
- When does it grow?
- Where does it grow?
- When does it die?
- What does it need to grow?
- Why does/doesn't it smell?
- Does it have brothers and sisters like I do?
- Does it belong to a family like I do?
- What is this leaf made up of?
- Can I eat it?
- Who can eat this leaf?
- Does its shape, size or colour change over time?
- Can its shape, size or colour be changed by planting it in different soils? By giving it different food?
- Do insects like to sleep on it? Eat it?
- How can we protect the leaf from insects? Animals?

And so on.

A word of caution: In the commonly-experienced hurry to arrive at the 'right answer', too often the brilliant question is missed, the sustained enquirer is ignored, and the exercise turns into one of ticking right versus wrong answers. It is strongly recommended therefore that the flood of enquiry be sustained through active encouragement of those who kept asking, right until the end of term/year.

Thinking: Following the flood of enquiry, it may be opportune (depending upon the level of understanding and interest of the class) to stoke the fire further through discussion. This is an important part of the process of drawing the child into the fold of timeless scientific enquiry, by connecting the questions asked by the child to prior questions/discoveries or present-day unknowns. Again, it is important to bear in mind that without unduly hurrying the child to think of answers to the questions asked in the Ask stage, this Think step should be used well to roll the questions over with the tongue, as one would a piece of candy. Suck it, taste it, feel its juice pouring down your throat! The important thing here is not to worry about answers, but to allow for bold and free thinking around each question, perhaps again in the form of further questions.

Questions spring up in the mind from our own level of understanding and knowledge. Therefore, the teacher would do well to pause and take some time in looking at questions asked through the screen of the following filters, continuing with the example of the *leaf*:

1. A question like "Why is this leaf green?" could be connected by the teacher to why anything appears coloured, do we all see the same colour, what causes the perception of colour in each person, etc. Thus, the child can be asked to draw a chain of questions, each inside a bubble, as it were, and see how one question in the first bubble is leading to the spurting of so many more questions.
2. Questions on the shape and size of the leaf can be connected by the teacher to our own shapes and sizes, that of animals and other parts of creation, and the class can together muse on possible links between function and shape/size of any creature. Would an elephant be an elephant if it were not so huge? Would a jackfruit be as tasty if it were not so big? etc.
3. Questions like 'How does the leaf grow?' could be connected to the story of the discovery of photosynthesis (see Box 1 below), which the teacher needs to go prepared with, to class.

Box 1: Photosynthesis

Too often, this topic is taught as if the entire mystery was just revealed to scientists by the flick of a wand. This writer visited a very interesting website: http://www.juliantrubin.com/bigten/pathdiscovery.html and culled the following information in less than twenty minutes of surfing. The teacher would do well to collect four or five such stories before taking up a new topic, so as to awaken the scientist within the child.

Is Water the Source of Energy in Plants?

Experiment I

Jan Baptista van Helmont, Flemish physician, chemist, and physicist, in the 1600s carried out a famous experiment by growing a willow tree in a pot for five years. At the end of this period the tree had increased in mass by 74 kg but the mass of the soil had changed little. Van Helmont believed that water was the source of the extra mass and the plant's source of life. What could the other possibilities be? How would you test out each of those possibilities?

(Sequence of experiments as they were performed historically, follows.)

Experiment II

John Woodward, a professor and physician at Cambridge University in the late 1600s, tried to design an experiment to test Van Helmont's hypothesis that water was the source of the extra mass. In a series of experiments over as many as 77 days, Woodward measured the water consumed by plants. For example, one plant showed a mass gain of about 1 gram, while Woodward had added a total of almost 76,000 grams of water during the 77 days of plant growth - this was a typical result. Woodward correctly suggested that most of this water was "drawn off and conveyed through the pores of the leaves and exhaled into the atmosphere". So the hypothesis that water is the nutrient used by plants was rejected. (Teacher can describe the experiment and ask students to draw the inference.)

The Interaction of Plants With Air

In August of 1771, Joseph Priestley, an English Chemist, put a sprig of mint into a transparent closed space with a candle that burned out the air (oxygen was not discovered yet) until it soon went out. After 27 days, he relit the extinguished candle again and it burned perfectly well in the air that previously would not support it. And how did Priestley light the candle if it was placed in a closed space? He focused sun light beams with a mirror onto the candle wick (Priestley had no bright source of light and had to rely on the sun). Today, of course, we can use more sophisticated methods to light the candle like focusing light from a flood light through a converging lens or by an electrical spark. So Priestly proved that plants somehow change the composition of the air.

In another celebrated experiment from 1772, Priestley kept a mouse in a jar of air until it collapsed. He found that a mouse kept with a plant would survive. However, we do not recommend to repeat this experiment and hurt innocent animals. (Teacher can describe the experiment and ask students to draw the inference.)

Plants and Light

Jan Ingenhousz took Priestley's work further and demonstrated that it was light that plants needed to make oxygen (oxygen was discovered a few years earlier in 1772 by Carl Wilhelm Scheele). Ingenhousz was mistaken in believing that the oxygen made by plants came from carbon dioxide.

However, Jan Ingenhousz was the first person to show that light is essential to the plant process that "somehow purifies air fouled by candles or animals".

In 1779, Ingenhousz put a plant and a candle into a transparent closed space. He allowed the system to stand in sunlight for two or three days. This ensured that the air inside was pure enough to support a candle flame. But he did not light the candle. Then, he covered the closed space with a black cloth and let it remain covered for several days. When he tried to light the candle it would not light.

Ingenhousz concluded that somehow the plant must have acted in darkness like an animal. It must have breathed, fouling the air. And in order to purify the air, plants need light. (The teacher can describe the experiment and ask students to draw the inference.)

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How to make Science Interesting for Children

Yasmin Jayathirtha

Before one can talk about making science interesting for children, there are some basic questions that need to be asked and answered - 'How can science not be interesting?' and 'Why is school science boring?'

To answer the first question, science can be defined as the observation of the universe through the senses and with instruments that extend the scope of the senses. After this, we build models on how the universe works. Given this definition, it is hard to see how science cannot be interesting! It is the joyous exploration that all babies and toddlers do as they crawl around, watch things, pick them up, throw them, taste them and learn from their observations. One baby I know has just learnt that not everything bounces! Year by year, this learning is extended to make correlations and abstractions.

As regards the answer to the second question, without going into a questioning of the whole education system itself (though the answer finally does depend on that), we need to ask, "What are we trying teach when we teach science through textbooks?" Firstly, there is confusion between science and technology. Secondly, there is confusion about what constitutes scientific literacy, i.e. is science 'process' or 'content'? Thirdly, in our textbooks, we have dumped simpler content for more 'advanced' content, which has no grounding in what the children know. For example, the 10th standard SSLC textbook had the rocket equation and talked about rockets and satellites without having covered Newton's laws of motion or logarithms in mathematics.

Teaching science as a *process*, through which students learn *content*, will take away much of the difficulty that students face in learning this subject; that it bears no relation to the world they know and the difficulty of memorizing facts in isolation. There are excellent science textbooks and programmes, which follow the exploratory method. Eklavya's programme, Homi Bhabha Science Centre's Small Science Series of books (refer Pg. 62 for a review of these books), and NCERT's primary science texts, are a few examples. These have not been widely adopted in schools, in my opinion, because of one failing - they do not lend themselves to easy evaluation. It is very difficult to set tests for what students have learnt in an exploratory way; there are no facts that can be reproduced. The failing I mentioned is not of the books but of the system of evaluation itself. There can be no radical change in the way we teach and learn unless there is a radical change in the way we evaluate teaching and learning, and that is an exploration in itself.

> *"You cannot teach a man anything; you can only help him discover it in himself."*
> *-Galileo Galilei*

Very narrowly, let us say that science in the classroom should have an experimental approach for it to be meaningful and interesting to students. There are many reasons why a science teacher may feel apprehensive about adopting an experimental approach to the teaching of science. Experiments are expensive, disruptive in the classroom, potentially dangerous and take up too much time. However, the fact is that much of school science is actually experimental in nature and acquiring knowledge is easier through such an approach. It makes more sense to *show* that sodium is a silvery white metal that reacts violently with water, than to read out the statement. The dramatic demonstration also makes the fact easier to remember.

More importantly, when we teach school science through experiments, the students learn several important skills. They learn the skill of working with their hands, observation and data collection. At a deeper level, they learn that thinking about a process and bringing it fruition can be two very different things. This will help them gain a realistic perception of (and respect for) people who work with their hands for a living. They learn not to take any statement merely at its face value. 'How' and 'Why' are questions that will immediately come to their minds.

After talking in generalities, what can a teacher, having a large class and being bound to textbooks, do? We can bring in science as a process in many ways:

First, we can connect the material to everyday experience. This works very well for the primary and secondary levels. The standard V textbook in Karnataka has a lesson on levers, where levers and the various classes of levers are defined, in terms of effort, load and fulcrum. The teacher can give examples of levers, let the students find out what levers do, and ask them to observe and come back with examples of the use of levers in everyday life. These will range from crowbars to bottle openers to *chakkis*, and a lively discussion will follow.

Second, we can make connections by narrating the story of the discovery - Who found out, When, What experiments were done, What did the discovery mean? I teach the structure of the atom this way. The outline would include Dalton's model of the atom and the assumptions he made, flame tests by Bunsen and Kirchhoff, Mendelev's periodic arrangement based on properties, the discovery of radioactivity (a great source of stories and personalities), the discovery of the electron, Thomson's model of the atom, Rutherford's experiments and his model based on them, and Bohr's model linking it to the flame tests. This gives an overview of how the present model came about and therefore makes it easier to visualize, remember and apply. It takes me about six periods to tell this story. The flame tests are done as actual experiments.

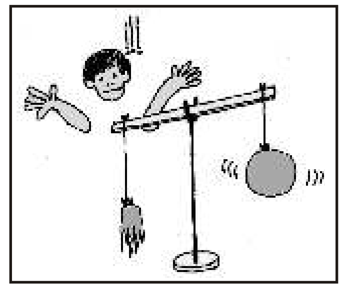
The third is to do demonstrations. This would be done for experiments that could be hazardous, or use expensive materials, or to keep a linear flow of discussion. I would do the flame tests discussed above as a demonstration, may be calling on the students to hold the salts in the flame.

The fourth is to do simple experiments, with easily available materials, on a micro scale, using, for example, ink droppers and plastic sheets, so that it can be done by students, at their desks. [See Box 2]

The fifth is to use an experimental analogy. [See Box 1]

Any science lesson will use a combination of the above methods. This approach puts a lot of onus on the teacher. S/he will have to constantly ponder on questions like, 'How can I illustrate this concept?', 'Which simple experiment will work?', 'What is a good example from daily life?', etc. In fact, I am still looking for a simple experiment to demonstrate Boyle's law quantitatively!

Good sources for experiments and for the design of simple equipment are, the internet, college textbooks, popular science books, UNICEF handbook for science teaching and most important of all, oneself. It is a lot of hard work to make science fun, but is deeply rewarding and will add to one's enjoyment of the classes. A word of caution though - Try out the



experiments before using them in the classroom, since, at times, they may not work as expected. Many books show an experiment to demonstrate that air has weight. It involves balancing two filled balloons tied to the ends of a ruler. Deflate one and the end with the filled balloon will dip (the books say), since the filled balloon is heavier. In fact, because of buoyancy, the filled balloon goes up!

Box 1 : To illustrate the concept of a Mole.

The mole is a measure of the number of particles and the connection to the mass that can be measured. Most students find the concept abstract and difficult to understand. An experimental analogy could be drawn by taking many different kinds of seeds - moong, double beans, rajma, groundnuts, dried peas, etc. Count out a hundred of each kind of seed and find its mass. If you don't have access to a balance, I am sure the nearest grocery shop will help! Calculate the mass of the lightest seed and call it hydrogen and give it a mass of one. You can determine the mass of the other seeds as a ratio to the mass of this seed. You can then calculate how many seeds there are in any given mass of any seed. You can then extend this to the idea of relative atomic mass as the average mass of the seed!

Box 2 :

Classification of Chemicals - Acids, Bases and Indicators.

Collect flowers of a particular kind (each child could use flowers of a different colour like hibiscus, vinca, jacaranda or marigolds), crush them with a little water and extract the juice. Divide the extract into three parts. Add lemon juice to the first part and '*choona*'/chalk water to the second. Observe the colour changes, if any.

Having found the extract that gives the best change, make a large quantity of the indicator, and ask students to bring in things to be tested. Suggested materials are milk, curds, orange juice, soap, shampoo, tea, oil, etc. One class discovered that acids are sour and bases are bitter. They extended the experiment to find out if all sour substances are acids and all bitter substances are basic!

Illustrations by Radhika Neelakantan, Centre for Learning, Bangalore.

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Questions asked by a Curious Student

When things can go from hot to cold,
Without trying at all, so I'm told,
Why can't they move from cold to hot,
And save us all the energy cost?!

Things from above fall to the ground,
They tumble down and land with a sound,
But when we throw them high in the air,
Why do they quietly move back from there?

When the planets can always have fun
Moving constantly about the glorious Sun,
Why is it that folk like you and me
Can't also move about unconsciously?

A vacuum cannot stay empty for long
For sooner or later air will rush along
And fill in the whole empty space,
Why, then, does air always win the race?

Why can't it be that air rushes out
Of any place in which it moved about
So as to leave, then, a vacuum behind,
Surely the air can thus get aligned?

And is there no way that we can make
A winding creeper move like a snake,
From the top of the tree to the ground below,
[They only climb upwards, as far as I know!]

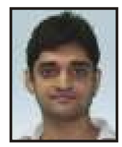
I wish to know the answers to these,
And many more such questions, please
Could you tell me where I can find
Befitting answers that will soothe my mind?

Remember, though, I don't want you to use
Long, difficult words, so do please choose
The simplest words in your vocabulary
So that I can understand you easily!

- Neeraja Raghavan

The Potential of Assessment in Science

Vishnu Agnihotri, Nishchal Shukla, Apoorva Bhandari

Background

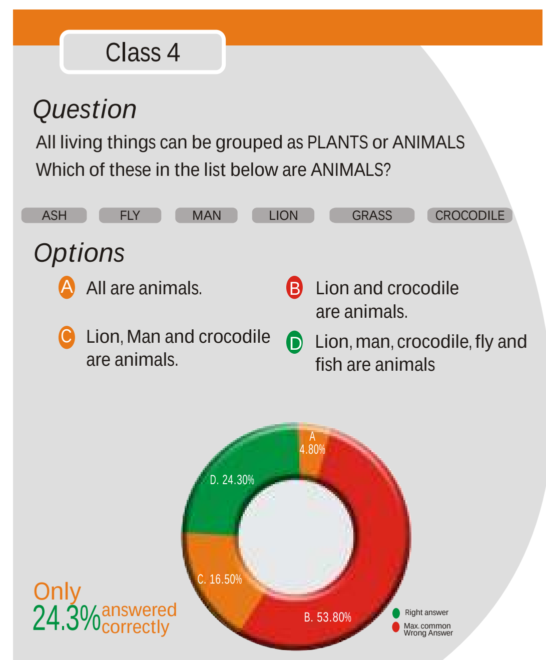
Before we speak of assessment in science, we need to understand what the goals of science education are, so that we may know what it is that we want to assess. The National Focus Group (of the National Curriculum Framework) document on the teaching of science lists “observation, looking for regularities and patterns, making hypotheses, devising qualitative or mathematical models, deducing their consequences, verification or falsification of theories through observation and controlled experiments” as the steps of the scientific method. The above stated process skills have to be developed while working on certain content, indeed, content in multiple areas. For instance, the skills of observation and looking for regularities (similar to classification into groups), for example, can be developed both while working with different types of leaves, as well as while working with different type of materials like glass, wood, steel, etc.

Stated simply, process and content are both important to science education. Thus science assessment, too, must focus on these two aspects, whether the assessment is a large-scale standardized test, a school quiz, or an informal assessment made by a science teacher, as she walks around class, listening to students. The focus in both teaching and assessment should be on important ideas, concepts and skills. The curriculum should not be, as somebody has said, ”a mile wide, and an inch deep”.

Some insights from our experience in large-scale assessment

We share some insights we have got from our experiences in large-scale assessment, along with examples. We hope this highlights the importance of the feedback that we can get from such assessments.

Lay ideas dominate scientific ideas

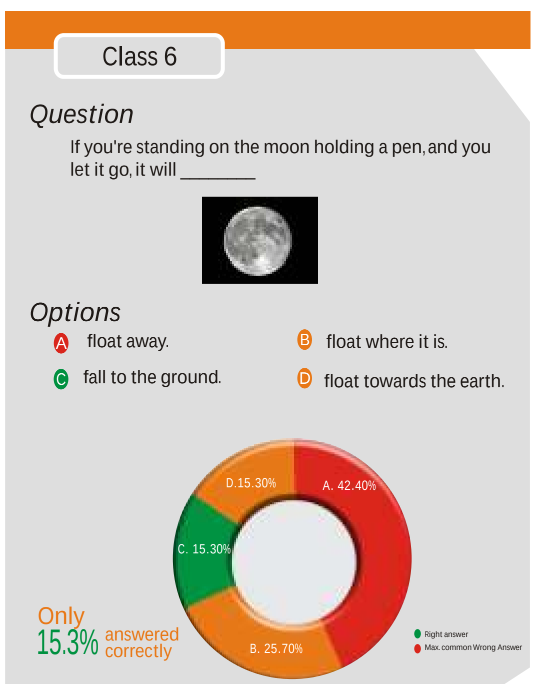


Source- ASSET (private English medium schools), No. of Students- 3365

The results of the above question show that over 50% of the students believe that only 'lion' and 'crocodile' are animals, and 'man', 'fly' and 'fish' are not animals. Common comments by students are that 'man used to be an animal, but no longer is', 'fly is too small to be an animal', 'fish is an aquatic creature'. This indicates that the lay usage of the term 'animal' dominates children's thinking, even though they may have been taught, in a science class, that all living things are grouped into plants and animals (which, in fact, is also stated in this question); the distinguishing characteristic being that plants make their own food from sunlight, whereas animals must depend on plants or other animals for food.

These results are not a comment on the ability of children, but highlight the need for educators to recognize the strong influence that lay terms and ideas have on children, and reflect on instruction that can address this. For example, getting such feedback might lead a science teacher to spend time eliciting student ideas on what an 'animal' is, clarifying the difference between the 'scientific' and lay meaning of a term, and stressing on the similarities between a man, a fly and a lion that qualify all of them to be 'animals'.

Prior mental models dominate



Source- ASSET (private English medium schools), No. of Students- 3668

These results and subsequent interviews with students show that the image of astronauts floating in space or spacecrafts has strongly influenced the mental models of children (and many adults). There are also many misconceptions about gravity and weight; it is seen more as a property of the object which 'allows it to fall', rather than as an effect of gravity. Many of the same students who answer this question wrongly can comfortably tell you that 'the gravity on the moon is 1/6th that on the earth'. If educators can recognize that children come to school with 'ideas of their own', then they can see their task as helping students to assess the efficacy of their ideas (or mental models) and help them replace these with more scientific mental models. A video series produced by the Harvard Smithsonian Centre for Astrophysics demonstrates this powerfully (http://www.learner.org/resources/series26.html). We have also produced a series of films based on student interviews, and can share a copy of these on request.

Other examples of misconceptions and their sources

Several such examples are seen in our work with both private English medium schools as well as the government schooling system. The following is a quick peek into some other types of examples-

- Textbook context rules ideas - Most textbooks, for the primary level, always refer to evaporation in the context of the water-cycle. This leads children to believe that 'evaporation' and the 'water cycle' are synonymous. Consequently, they do not believe that evaporation can occur from a glass of water, or a puddle, etc.
- Poor real-life observation - Time and again, student response data show that children are not encouraged to learn science through careful observation of day-to-day phenomena, like for example, how shadows are formed.

One interesting example is from a study we did on municipal schools across five states in the country. Students of Class 6 of these states were asked the question (in their local language)-

Which of these is furthest away from us?

A. clouds

B. a flying crow

c. the Sun

D. the moon

30-50% of students answered that clouds are furthest away from us! The response data to this question makes us wonder whether schools are actually helping in learning at all!

Assessment data - a goldmine of insights

We believe that as more and more stakeholders recognize the power of large scale assessment, there will be further investments of effort into deriving many more types of insights from assessment data. We share, below, one example of what else might be possible to glean from data. This analysis shows how even five years of schooling has virtually no impact on addressing a misconception on the concept of respiration.

The question asked of students from Class 4 to Class 10 was -

Which of the following are examples of respiration?

1. Humans use oxygen and release carbon dioxide.
2. Plants use carbon dioxide and release oxygen.
3. Burning dry leaves uses oxygen and releases carbon dioxide.

A. only 1

B. only 2

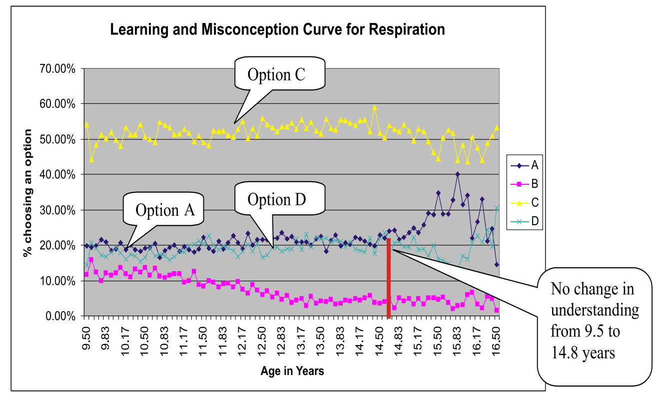
C. only 1 and 2

D. 1, 2 and 3

The correct answer is A- Only 1. Process 2 is the process of photosynthesis; even many adults do not realize that plants are taking in oxygen and giving out carbon dioxide simultaneously and continuously in order to respire and provide energy for their life processes. Process 3 is the process of combustion.

The student response data across all these classes is shown in the graph below. Students were aged from 9.5 to 14.8 years.

The data clearly show that children continue to answer C (thinking that photosynthesis is 'how plants respire'), and there is virtually no change in their understanding across over 5 years of schooling. And this is a period during which they learn about the entire human body and all its systems including the respiratory system. They also learn about plants and photosynthesis along



with the chemical reactions taking place. They learn about the carbon cycle, and the basics of chemistry and chemical reactions. But clearly, there's little to show that all this is actually being 'learnt'.

Parting thoughts : Interpreting and acting on assessment data

As we have seen above, assessment does provide valuable data and insights into how we are progressing towards our goals as an individual, class, school, or a nation. Creating a culture of data-based analysis and decision-making can lead to a focusing of efforts and fruitful issue-based dialogue between stakeholders.

However, one needs to be aware of the risk of blindly accepting assessment data without understanding the context, and reacting to data in a knee-jerk fashion. When scientifically generated assessment data points to significant gaps in learning, defensiveness can be a natural reaction, especially when 'official' statistics show a much rosier picture. For a system to accept the 'true metric', and face the reality of the current situation, can be scary, but there is no choice if we truly want to improve learning. As Jim Collins, the author of 'Good to Great' says, “Great organizations confront the Brutal Facts (Yet Never Lose Faith)”. We could extend this to systems as well.

While interpreting assessment data, do make sure you ask relevant questions, such as - What was the question given? How was it administered? Under what conditions did students take the test ? How was the sampling done? How has the statistical validity been determined? What do field interviews with students say? It is only when one gets into such details, can one get an accurate and well-rounded view of what the data is telling us.

Assessment as an integral part of learning

Is assessment only about results from large scale tests? Not at all! Assessment is an integral part of the learning process. It is about the teacher and learner getting feedback; it is about recognizing and clarifying goals, and always keeping the 'end in mind'. In fact, it is impossible to separate assessment from the process of learning.

Our experience is clearly beginning to show that assessment can be used for learning in new and different ways. We are currently working with children in both private and government schools with a question-based adaptive learning system called Mindspark that has been developed for Maths. The system uses 'finely-graded questions', meaning questions that successively address higher and higher concepts but with a very, very slight increase in complexity between the concept(s) tested in one question and the next. Such question-based assessment systems can be valuable tools to provide personalized learning support to complement group teaching that happens in the class. Rigorous early tests are showing encouraging results that children like to answer the questions, and there is a statistically significant improvement in their learning levels. The development of Mindspark Science modules is currently underway.

We hope this article has shed some light on the power of assessment in science, and assessment in general, and encourages a deeper investigation into assessment practices and the use of assessment data by all stakeholders in education.

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CRITICAL ROLE OF THE TEACHER

Developing Teachers

Kamal Mahendroo

A 1929 text for science teachers describes a successful science teacher as one who:

"...knows his own subject ... is widely read in other branches of science ... knows how to teach ... is able to express himself lucidly ... is skillful in manipulation ... is resourceful both at the demonstration table and in the laboratory ... is a logician to his fingertips ... is something of a philosopher ... is so far an historian that he can sit down with a crowd of [students] and talk to them about the personal equations, the lives, and works of such geniuses as Galileo, Newton, Faraday and Darwin. More than this, he is an enthusiast, full of faith in his own particular work."

Eighty years later this still holds well, though one might like to add some more caveats to this description of an ideal science teacher, apart from over writing the gender bias. While this may sound too idealistic to achieve, it helps in giving a perspective for teacher education. How to design a teacher education program that may achieve this goal? More specifically, what should happen in a good teacher training?

In interactions with teachers I try to engage them in exploring a particular question or concept rather than giving a lecture (or power-point presentation) on the principles of good science teaching. One such question is about falling bodies. If we drop, from a height, a heavy body and a light body together at the same time, which of the following is expected to happen:

(a) The light body reaches the ground before the heavy body.

(b) The heavy body reaches the ground before the light body.

(c) Both reach the ground at the same time.

Interestingly, invariably a large majority opts for option (b). Initially their response provoked a sense of dismay at their knowledge of high school science. But one can understand the cause of this confusion. Our daily experience reminds us of dry leaves, pieces of paper or feathers drifting slowly to the ground as compared to a stone falling. Even the great Greek philosopher Aristotle surmised that the speed of a falling body would be proportional to its weight. Galileo, nearly two thousand years later, questioned his view by dropping a canon ball and a musket shot from the Tower of Pisa. Educational researchers have identified this as the problem of transition from naive or intuitive to counter-intuitive conceptualizations.

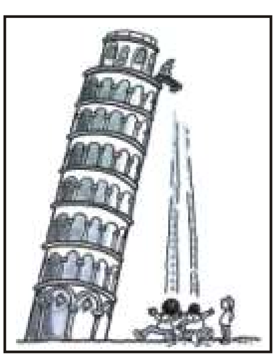
Inclusion of such conceptualizations in a list of "hard spots" and repeated attempts to explain them does not solve the problem. There is a need to initiate a process of rationally re-examining the conceptualization with the students/teachers. Often this process can begin with an experiment that provokes the thinking process.

A simple experiment with a note-pad and a page taken out from it makes a good beginning. Releasing the paper and the note-pad from a height (enough to stand on a chair or a table) simultaneously, confirms Aristotle's surmise.

What if we place the paper right under the pad and release them simultaneously? Everyone agrees that the heavier pad will take the lighter paper with it and both will hit the ground in the same time. The experiment demonstrates a minor success of an experiment confirming theory!

In the next experiment, the paper is to be placed on top of the pad totally aligning with it. Which will reach the ground faster - the paper or the pad? I have seldom found doubters that the heavier pad will leave the lighter paper far behind. The experimental result often leaves a surprised silence. Try the experiment yourself and see the paper fall with the pad! Some would even like to come and try it themselves, suspecting some trick behind it - they deserve to be welcomed and encouraged in the true scientific spirit.

An animated discussion follows. Are we right in assuming that a heavier body will fall faster than a light body, in proportion to their weights? A consensus emerges that the difference in this case was probably due to the difference in resistance offered by air during the downward journey of both the objects. Yet there are skeptics enough who cannot accept the idea that weight probably is not a factor at all. This is when the situation is ripe for the next experiment. The same paper is crushed into a tight ball, and the note pad and the paper ball dropped again. They almost seem to fall together, but doubts are expressed whether they were dropped at exactly the same instant or not. It excites some groups to get up and devise methods of ensuring that the paper ball and the pad are released exactly from the same height and at the same time. They also want to ensure that the time of hitting the ground is observed as accurately as possible for both the objects. Mobile phones, with stopwatches measuring time up to a hundredth of a second, are often available in teachers' pockets. 'Wasting' some time in devising as accurate an experiment as possible, and trying to evolve an empirically verifiable conclusion about the three statements, is more than worth it.



It is now time to bring in Galileo and his experiments with a 100-pound cannonball and a half-pound musket shot. Our crude paper ball and notepad experiment is a repetition of the experiments that he is said to have performed from the Tower of Pisa. It convinced him to claim that Aristotle never did an experiment to verify his surmise and hence was incorrect. But he went on to develop the argument in an interesting way. The argument is narrated in his book Dialogues on Two New Sciences. The dialogues take place between three interlocutors - Salviato presenting Galileo's own arguments, Simplicio propounding Aristotelian views and Sagredo, a neutral rational-minded interlocutor commenting on the dialogues between the two. One can dramatically narrate various aspects of Galileo's life and work but the essence of the argument relevant to our theme follows.

Accepting Aristotle's surmise, if we drop the two balls tied together, theoretical logic can lead us to two conclusions. Since the lighter ball takes more time to fall, it will retard the speed of the heavier ball, and the two together will take more time than the heavier ball in reaching the ground. However, if we consider their combined weight, it is more than the heavy cannonball and should therefore take less time than the heavier ball. The two deductions are both logical but contradictory. Galileo asserts that this implies that the initial surmise is not tenable and that the weight of a body directly does not affect the time taken or the speed of falling. The difference that we perceive is because of the resistance offered by the medium in which the body is falling, which depends on various combined factors like shape, density of the body's material, density of the medium, movement of the medium itself, etc.

Galileo then took a logical jump of imagination to say that in a medium-free situation - a vacuum - a lighter and a heavier body will fall exactly in the same time. It needs patience and repetition to help every person in the group to absorb this theoretical argument. Training in such logical argumentation is as essential a part of learning science as developing experimental skills.

In 1971, the astronaut David Scott, of the Apollo 15 mission to the moon, dropped a hammer and a feather. The video shows both of them falling at the same speed reaching the ground together on the airless surface, experimentally confirming Galileo's logic.

In further discussion, one can point out a very significant aspect of this conceptual development. Galileo's experiments did show that Aristotle's surmise was not correct but given the effect of air, he could not confirm his own assertion with total accuracy, as recorded with full honesty and amazing precision. It took two decades of painstaking experimentation and theory building to make the assertion that introduced two new ways of doing science - idealization and thought experiment. There can be a number of interesting questions to put before the class to excite them and lead them to deeper enquiry. How could a wise man like Aristotle make such an assertion? What were the theoretical premises that led him to that? Can we still say that in a perfect vacuum on another planet, the hammer and the feather will fall in precisely equal times? Some of these questions are still open questions of science, and more can be thought of.

An important question raised is - would the teachers have now acquired deep enough understanding to tackle questions like the one we began with? The answer can be - maybe or maybe not. But what one can say with confidence is that they would have embarked on a conceptual journey that can now take them to Galileo's investigations with inclined planes and pendulums and onwards to Newton's laws of motion and gravitation, deepening their understanding of motion; as Newton put it, "…(prepare them) to see beyond, from the shoulders of giants". Excited and serious responses and questions from teachers, after such sessions, are most gratifying and encouraging.

It now remains to put down the assumptions behind adopting such an approach. The way we teach science and do science is crucially dependent on the dual understanding of its method and its conceptual structures. This dual understanding goes along with our ability and confidence to practice science. As Einstein put it with great clarity :

"There is no empirical method without speculative concepts and systems; and there is no speculative thinking whose concepts do not reveal, on closer investigation, the empirical material from which they stem."

> *"Every great advance in natural knowledge has involved the absolute rejection of authority."*
>
> *- Thomas H. Huxley*

Use of History and Philosophy of Science reveal to teachers and students how the method and the conceptual structure evolved. Retracing some of those crucial steps, help in developing their understanding and the skill to use it. It brings out crucial values associated with scientific practice - skepticism, not accepting any dogma based on authority, and the crucial role of evidence and rational reasoning in drawing or defending inferences.

Along with consolidating their knowledge of the subject and the skills associated with it, this approach exposes the teachers, and through them the students, to the central question of what is knowledge, epistemology and the goal of all education. It also gives them another view of sociology of science, its ethics and values. It all amounts to a much maligned term - 'scientific temper' - a commitment in the Indian Constitution.

We are more used to teachers being talked down to, of how they should teach and what they should teach. It is time for the teacher educators, curriculum designers, administrators and policy makers to show in practice what they preach to the teachers. In doing so, they will also counter the usual criticisms of such approaches being too time consuming and how the entire syllabus would not be covered this way. The central issue is not the syllabus but the goals of our education.

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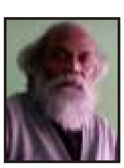
The Agency of School Teachers

Vijaya Varma



Experiments with reforms in school education in India, like the Hoshangabad Science Teaching Programme, have shown that teachers are critical to the enterprise of quality education. Whenever a teacher buys into the idea of reform, the reforms stand a chance of succeeding, but whenever a teacher is hostile or indifferent, the reforms are headed for failure.

The normal process of curriculum development or textbook preparation, particularly when steered by organisations like the NCERT, is a highly centralised activity characterised by a very hierarchical, top-down approach, in which most of the wisdom is supposed to reside in the organisation or the panel of 'subject experts' drawn up by the organisation, with (at best) only a token involvement of some teachers who are chosen primarily for ease of availability. Such efforts usually ignore the fact that in developing a curriculum (that stands a chance of being successfully implemented), one must not only be responsive to the demands of the discipline, but also take into account the conceptual development of the children for whom it is meant, the resources that are available in the schools and, most importantly, the readiness and the preparation of the teachers who are actually going to do the teaching. The only way this can be done is if the team that is charged with the responsibility allows teachers from the field to be central to the process. The team should also not be so prescriptive in its approach that no space is left for the teacher to own the curriculum, by incorporating his/her own views and experiences into the teaching process.

To appreciate what we have just said requires no great effort. So the question is why are these principles to be found more in the breach than in the observance? In the remainder of this brief article we will try and examine some of the reasons why this could be so.

One major reason that we have hinted at is the propensity of the system to try and retain control and not allow any significant decentralisation to take place. Consider the most recent exercise by the NCERT to draw up first the National Curriculum Framework (NCF) 2005 and then develop the syllabi and school textbooks based on this document. Experts were flown in from all over the country in an attempt to spread the net of consultations countrywide. In my opinion, however, the effort would have yielded much better results had this not been centralised in Delhi but been carried out in, say four regional centres to start with, and allowing them to function more or less autonomously once the national framework was ready. This would have led not only to four independent sets of syllabi and textbooks, something that the NCF 2005 itself suggests as a desirable goal, but would also have given a boost to the development of regional competencies and promoted decentralisation. It would have opened up possibilities of greater involvement of practicing school teachers in the whole process of curriculum development and the writing of textbooks. One of the arguments against contemplating such a step is the assertion that there are not enough regional competencies available to make the effort worthwhile. But this is the classic chicken and egg problem. How will regional competencies develop unless they are specifically encouraged?

To some extent, it has to be conceded that the average competence level of school teachers, for a variety of sociological and educational reasons, is not what it should be. So what can we do about it? It is almost a given these days that only those 'who can do no better' end up as school teachers and the government doesn't help in the development of a professional cadre of school teachers by aggressively following policies like the recruitment of para-teachers - policies which, at their heart, are meant to lower the costs of providing education, while simultaneously curbing the powers of teachers' unions. What is forgotten, in all this, is that the quality of school education cannot be improved without improvement in the quality of school teachers. And the only way this can be done is by making the working conditions - and I don't mean only salaries - more attractive in order that talented individuals are once again attracted to the profession. This would require providing better facilities in schools and a better working environment for school teachers - better surroundings, better infrastructure, better working conditions, better libraries and laboratories and taking proactive steps to freeing teachers from the widely prevalent hegemony of even the smallest functionaries of government departments of education.

It is becoming fashionable in seminar circuits to recognise the centrality of the agency of school teachers for imparting quality education in schools. What it would ensure, were it to be translated into practice, is to improve not only the academic quality of school teachers but also their commitment to teaching. The increasing incidence of teacher absenteeism in schools is a matter requiring urgent attention. I believe that it is very difficult to solve this problem merely by legislating teacher accountability. Clearly some action is required to ensure that teachers attend school regularly, but this is only a prerequisite, because those teachers who have no compunction about staying away from school are not going to start teaching merely by the government passing legislation that they be present in class. It may be tempting to hold teachers accountable for the performance of their students, but how do you do this in a regime in which there is less and less emphasis on assessment in the lower classes, where most of the damage is done by teacher laxity, under the pretext of not exposing students to the trauma of failure?

Clearly then it boils down to a matter of values - that one should perform one's duties to the best of one's abilities without being compelled to do so. There is growing evidence in our society of a casual approach to the values of accountability to one's professional commitments, of which teacher absenteeism and lack of performance is but one manifestation. A possible reason for this is that with the steady break-up of family traditions and the growth of crass commercialism in the ranks of the middle-class, under the onslaught of modernism, children get fewer and fewer opportunities to imbibe good values at home. In schools, the other source from which children could pick up good values, the situation is bedevilled both by the bad example that teachers often set and also by the problems associated with formally teaching morals and values in a multi-cultural and multi-religious society. Whose morals and whose values do you teach? And because such questions have traditionally been rooted in religious discourse, there have been no commonly acceptable answers and we have ended up teaching none. I think the time has come to locate such discourses outside religion and develop a basis that is founded on reason and rationality for the teaching of such subjects in school. Hopefully, having to teach such courses and being exposed to such discourses, will bring about a change both among the teachers as well as the general population, leading to a greater commitment to professionalism and accountability - ends which are much to be desired.

To summarise, what we have argued in this brief article is that good and committed teachers are central to a good system of education in schools. Teachers should have a greater role in the development of syllabi and textbooks and for this, these processes need to be decentralised. We must also attract better quality people into the profession and for this, we must not only improve salaries but also the working conditions of teachers and the facilities available to them. However, all this will come to nothing unless we simultaneously improve teacher accountability by both legislative processes as well as by inculcating a proper sense of values in our teachers and our students through our system of schooling.

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HISTORY OF SCIENCE

Journey Of Science Through Time

Nandita Narayanasamy

Trying to organise my thoughts about the history of science, the first thing that sprang to my mind was the current advertisement of a health drink for children. The advertisement states that Nature and Science are present together in the product which accounts for its superiority as a nutrient supplement! The company makes us believe that Nature provides the complex nutrients and it is Science that provides the minerals. If one applies logic, to this otherwise illogical advertisement, the outcome is that minerals are not part of nature! Pardon my ignorance, but I was under the impression that Science has always been the study or enquiry into the workings of Nature! If one looks back in literature, both European and Asian, the close association of the awe of nature and mankind's quest to understand and harness its power is very apparent. This whole episode made me introspect on our understanding of science and how this perspective has changed with time.

The word science comes from the Latin word, "scientia", meaning knowledge. Science is the effort to discover and increase human understanding of how physical reality works. Science is the total collection of knowledge gained by observation of the physical world using our five senses, to investigate the world that exists in the present. If one looks into the Oxford Dictionary, science is defined as the intellectual and practical activity encompassing the systemic study of the structure and behaviour of the physical and natural world through observation and experimentation.

Tracing the exact origins of modern science is possible through the many important texts which have survived from the classical world. Many ancient civilizations collected astronomical information in a systematic manner through simple observation. Though they had no knowledge of the real physical structure of the planets and stars, many theoretical explanations were proposed. Basic facts about human physiology were known in some places and alchemy was practiced in several civilizations. From their beginnings in Sumer (now Iraq), around 3500 BC, the Mesopotamian peoples began to attempt to record some observations of the world with extremely thorough quantitative and numerical data. The pre-Socratic philosopher, Thales, dubbed the "father of science", was the first to postulate non-supernatural explanations for natural phenomena such as lightning and earthquakes.

While such empirical investigations of the natural world have been described in various ancient civilizations, including Ancient Greece (for example, by Thales, Aristotle and others), records of the use of scientific methods having been employed appear in the Middle Ages. Ancient India was an early leader in metallurgy, as evidenced by the wrought iron Pillar of Delhi. They excelled in the manufacture of iron, and in the preparations of those ingredients with which it is fused, to obtain that kind of soft iron which is usually styled 'Indian steel'. They also had workshops wherein the most famous sabers in the world were forged. Ancient China was home to four great inventions: the compass, gunpowder, papermaking and printing.

However, the dawn of present-day science is generally traced back to the early modern period, during what is known as the Scientific Revolution, which took place in the 16th and 17th century, in Europe. Also, the word scientist is relatively recent - first coined by William Whewell in the 19th century. Previously, people investigating nature called themselves natural philosophers.

Scientific methods are now considered to be so fundamental to modern science that some people, especially philosophers of science and practicing scientists, consider earlier inquiries into nature to be pre-scientific. Traditionally, historians of science have defined science sufficiently broadly to include those inquiries.

A broader, modern definition of science may include the natural scientists along with the social and behavioral sciences, defining it as the observation, identification, description, experimental investigation, and theoretical explanation of any phenomena. However, other contemporary definitions still place the natural sciences, which are closely related with the physical world's phenomena, as the only true vehicles of science.

One overriding sentiment that runs through the above narrative is the emphasis on observation. Scientists are expected to be unbiased observers who use the scientific method to conclusively confirm and/or conclusively falsify various theories. These experts should have no preconceptions in gathering the data and should logically derive theories from objective observations. Another great strength of science is that it is self-correcting, because scientists readily abandon theories when they are shown to be irrational.

Science should therefore be, in my opinion, a project whose goal is to obtain knowledge of the natural world. To me, science is a way of life that encourages thought and promotes a sense of healthy enquiry into any aspect that touches human existence. However, a philosophical definition of science would be that it is basically an ordered and studied matter of questioning. And the pursuit of science has to be the pursuit of understanding, leading to further in-depth questioning.

However, today's Science Education, particularly in India gives scant importance to both observation and enquiry. In fact, both these necessary capacities are progressively discouraged in students, reducing them to a band of unthinking zombies, incapable of any analytical abilities. Science, unfortunately, has been reduced to a mere subject, a part of a curriculum that encourages information retrieval rather than exciting enquiry. A student of science is expected to be primarily hardworking , a conformist , non-rebellious and compliant. A child who is fun-loving or a dreamer, with revolutionary ideas and who asks uncomfortable questions is discouraged and thought 'unsuitable for science'.

If one looks back into the aforementioned advertisement, the depiction of science is that of a robot. Here, we arrive at another affliction that torments science nowadays - science has become synonymous with technology. The history of science has been marked by a chain of advances in technology and knowledge that have always complemented each other. But, one needs to remember, they are two independent entities, and technology is the outcome of science that supports further understanding. For a long time now, in India, technology has always had a superior edge over the pure sciences which accounts for the rush for engineering over a B.Sc. degree. This attitude in society has not changed; recently a student of mine left a B.Sc. Honors course in Delhi University to take up an engineering course in some god-forsaken private engineering college in interior Uttar Pradesh: the reason being, it would improve her prospects of obtaining a suitable groom in the marriage market!

Leonardo da Vinci may seem an unusual person to bring up when talking about science. But the more one learns about this remarkable Renaissance polymath, the more one realizes that he was a terrific role model for applying the scientific method creatively in every aspect of life, including art and music. Although he is best known for his dramatic and expressive artwork, Leonardo also conducted dozens of (carefully thought out) experiments and created futuristic inventions, at a time when modern science and invention had not really begun. Leonardo's approach to science was an observational one. He tried to understand a phenomenon by describing and depicting it in utmost detail, and did not emphasize experiments or theoretical explanation. As usual, because he lacked formal education in Latin and mathematics, contemporary scholars mostly ignored Leonardo, the scientist.

The reason for the story of Da Vinci is to emphasize the demarcation that has infiltrated our pursuit of knowledge. The arts and sciences are not expected to mix, they are mutually exclusive! Furthermore, the sciences themselves have been shredded into innumerable sub-fields, each maintaining their own snooty distance from each other. Thus the social perception of a scientist in India today is that of an asocial, non-creative entity who remains boxed in her/his own unreal world of the laboratory, the very thought of which is enough to drive off students from the field, in droves.

Thus the journey of science that began as an integrative understanding of nature has deteriorated into an unhealthy amalgam of 'subjects' that maintain a parochial disdain for each other. The positive note is that we have diagnosed the problem and that is the first step towards treating the malady. The following words of the great scientist Albert Einstein should guide us in our pursuit of knowledge: “A little knowledge is dangerous, so is a lot of knowledge, but the main thing is never to stop questioning.”

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Did Scientists Ever Err?

Neeraja Raghavan

We often teach children about the genius of scientists, but seldom talk of the errors they made. This leads children, naturally, to regard the entire process of discovery as being magical, like a rocket that takes off and zooms straight into its target: always. It is essential that we infuse our teaching of the subject with real life instances of erroneous thinking as well, as this demystifies the entire process of discovery and brings it closer to the learner and teacher of science. In addition, it shows us how we are ever in an ongoing iterative process of thinking, rethinking and revisiting many so-called 'truths', and how this is what learning is all about. The Internet contains a plethora of information on the history of science, and there are many excellent books on the subject. [One of the finest among such books is A HISTORY OF SCIENCE by John Gribbin.] As it is impossible to do justice to such a topic in these few pages, we present below a smattering of examples to show how erroneous thinking has long been a part of scientific discovery, like it is a part of human lives.

- For over 400 years, the Alexandrian School of Medicine taught that arteries carried air! Galen had to actually test this out in the second century AD and find that they carried blood, after which people had no choice but to drop this erroneous belief. Galen did make some significant contributions to the medical world, as he was the first physician to make use of the pulse rate to diagnose any illnesses of patients and was successful to a great extent.
- Galen (about 129 AD to 210 AD) proposed that blood is produced continuously in the liver and considered blood to be a combustible fuel for the body. He did not believe in the double circulation of our blood and thought that blood was the result of direct conversion from food. People believed him so implicitly that they held onto this belief for 14 centuries! Only when William Harvey dared to question this assumption in 1628 did the circulation of blood get discovered! Harvey first considered the circulation of the blood, when noting how much blood is expelled by the heart with each contraction: over the course of a full day, the amount was more than the body's intake of food by weight. Doing rough calculations, Harvey easily proved that the point is beyond doubt, and that the blood must be re-used. From here, circulation is but a short leap.
- In the early part of the nineteenth century, Lamarck proposed some correct and some incorrect theories about evolution. Amongst his incorrect guesses were: a flamingo's legs get longer because the flamingo is always stretching up to avoid contact with water, and secondly, that acquired characteristics can be inherited. Darwin and Wallace were more or less in agreement on the origin of species, and what is remarkable is that while the former drew his conclusions largely from detailed observations made during his nautical sojourn, the latter did so by adding voracious reading to rock survey: he devoured books from Malthus and spent four years in the forests of Brazil, exploring and collecting samples. Students' and teachers' take off points from the above: How can mere observation be aided by reading that goes along with it? Can you classify leaves and flowers with (a) just observation (b) reading as well as observation and compare your results? How have scientists' thinking about the evolution of life changed from Lamarck to Darwin? What do they think about the inheritance of acquired characteristics today?
- Aristotle said that a hundred pound ball falling from a height of one hundred cubits hits the ground before a one-pound ball has fallen one cubit. Galileo said they would arrive at the same time. Students' and teachers' take off points from the above: How would you find out who is right? Why do you think one of them erred?

- Just by contemplation and by virtue of his social status, Aristotle (384-322 BC) propounded the theory that the Earth was at the centre of the Universe, the Sun and all other planets moved around it and everyone accepted this. It was common sense that the solid Earth could not be moving. Copernicus came along in the sixteenth century and tentatively suggested the reverse, i.e. that the Sun was at the centre and that the Earth and other planets revolved around it. But Copernicus, too, did not arrive at this conclusion through observation. He did so by thinking. Students' and teachers' take off points from the above: Then, in the latter half of the sixteenth century, even when Galileo had proof with his telescope that Copernicus was right, why did he meet with opposition and imprisonment? What are the cherished beliefs we hold onto, that we hate to let go of, even in the face of sufficient evidence to the contrary?
- Van Leeuwenhoek's discovery of tiny moving creatures in droplets of water: until then, people assumed that water drops did not have any living things in them. Students' and teachers' take off points from the above: Like this, what are the assumptions we make about things around us? How can we prove them wrong/right?

With examples like the above serving as a launch pad, the teacher can move on to exciting classroom processes, which will undoubtedly provide rich learning experiences for both the teacher as well as the taught.

It is said that while testing the right material for the filament of the bulb, Thomas Edison had to try thousands of different filaments to select the right materials to glow well and be long-lasting. Eventually, he hit upon the right one. When asked by a news reporter how it felt to fail thousands of times before he finally succeeded, he replied: "I did not fail even once! My experiment simply had thousands of steps."

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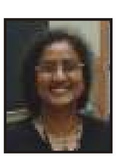
WHY I CHOSE SCIENCE?

A Quest for Understanding

Usha Ponnappan



When I tried to introspect as to why I chose Science as a career path, it was truly the very first time that I had delved into my past as a student, trying to search through my memory bank for that one special moment in my life that was a turning point. However, while it became clear that no one specific event set the stage for my future in science, it was, I think, a series of unrelated events that shaped my thinking that ultimately led me down this adventurous path, that I so cherish today.

Unlike writing a scientific manuscript, where one outlines the experimental design and a series of results that are leading to outcomes, this exercise of writing about my choice of Science as a career, largely relies on my memory and perhaps on some anecdotes of events in my early life. I cannot state with certainty whether it was my flair for life sciences or if it was the influence of my mentors along the way, that made it second nature to me, but I always gravitated and did well in biology.

The turning point, if I could call it that, was when I received the National Science Talent scholarship at the completion of high school. This merit scholarship provided by the Government of India fostered building future scientists on the path of basic science. One important facet of the National Science Talent scholarship examination that remains etched in my mind is my choice of a project report that I submitted for the scholarship application. It was in an area of cellular communication in the nervous system. Incidentally, while communication in the nervous system and action potentials still peak my interest, my major focus now centers on how cells communicate in the immune system. Looking back at my career and my choice, I would say that being awarded the science talent scholarship opened doors that would not have been easily accessible otherwise.

Science talent scholarships, provided by the Government of India (NCERT), are structured to select those students with a talent and aptitude for basic science, and encourage them to develop as the next generation of scientists. I truly believe that this opportunity afforded to me provided a strong impetus and encouragement to pursue my ambitions. It is initiatives such as this that will help fulfill our ambitious goal of promoting science and in making our younger generation competitive in this global economy. Additionally, the NCERT scholarship was tailored to provide research intensive training during the summers of undergraduate and masters programs, to mould and train young minds towards research inquiry. I feel that, at least in my case, the program was a success. Since I had the aptitude for research, the encouragement and opportunities provided were tailor-made. The scholarship, needless to say, helped me in my choice of institution for my graduate studies and in selecting a well-recognized scientist as my mentor. This was a gift, considering that most of my colleagues had to pick what was available rather than have the luxury of picking laboratories of their choice.

Now, to the larger question: Why did I become a scientist? The grandeur of solving questions is in itself sufficient motivation. However, I felt that one of the best things about being a scientist is the pursuit of understanding the workings of a paradigm, be it in biology or medicine. Added to this, is the ability to translate the understanding into effective therapies for the improvement of the health of an individual. A quest for understanding is ultimately what drove me to where I am today - the challenge, opportunities for innovation and problem solving that science provides. As a scientist, one can continue to ask questions with a child-like curiosity.

"There are two possible outcomes. If the result confirms the hypothesis, then you've made a discovery. If the result is contrary to the hypothesis, then you've made a discovery."

- Enrico Fermi

During the days of my graduation, my goal was to work on mechanisms and translational initiatives in the newly-developing field of reproductive immunology, with the intent of developing vaccines for contraception. This was driven by the desire to aid in the growing need for population control in India. Soon, as a budding graduate student, I realized that though my goals were lofty, the pursuit of those were challenging at the bench. Nevertheless, I look back on my graduate education at the Institute for Research in Reproduction, an ICMR institution in Parel, Bombay, with fond memories. This is the place where I learnt the essence of scientific inquiry and the reality of how every experiment, whether it produced expected results or not, eventually taught us something. It was here that I honed the skills of inquiry, scientific presentation and communication.

My recollections and experiences of how science is taught in schools and how it could be different, is something that I have dwelled on, for a long time now, since I have been intimately involved in teaching at the graduate level and in the medical school, here at the University. As a teacher, I derive the greatest pleasure when I teach by questioning, rather than by merely telling or stating facts. I find that my students learn the most when they are interactive, such as designing experiments or framing apt questions for testing a model. However, if my recollections are correct, science was often taught in our schools as direct transfer of information with the hope that students would rote memorize and recall the information in tests designed to precisely examine this method of gaining knowledge. Little, if any, emphasis was placed on the idea of conceptual knowledge and gaining of insight into an area, by questions designed to test the hypothesis. While questioning was encouraged, and was often directed at the students, interactive question-answer sessions were largely restricted to review sessions, which were too few to recount. I personally think that hands-on experience that we had in our high school curriculum, doing experiments in laboratories, be it chemistry, physics or biology, perhaps laid the ground work for the development of technical and problem-solving skills. More time devoted to such concrete methods of hands-on experiments, to see how science works, will clearly help develop a cadre of young individuals more driven to science. Now that we live in an information-rich society and with the availability of excellent text books/other resource books, students should be advised to read the material before they come to class, and classroom teaching should be devoted to discussions and intellectual interactions. Time should be provided to assimilate concepts, and insights should be provided in areas of focus, such that the time in the classroom is utilized to assimilate knowledge and think.

I truly believe that such a re-focus of classrooms will revolutionize teaching and empower our students to be life-long learners and enthusiastic problem-solvers. This clearly means that we, as a nation, have to invest in teachers - teachers who are highly skilled - for they alone can be beacons, leading our nation's young into a bright and challenging future, with an inherent quest for understanding.

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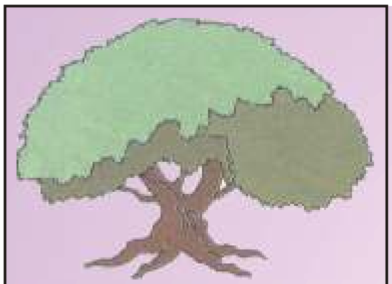


"Why is it, sphinx, that the barks of trees
Can't have just any colour they please,
Brown in colour, all look quite the same,
But trees differ in flower, fruit and name?"

Barks In Uniform

Nature has used her paintbrush to splash colours over flowers, fruits, birds and animals, but she seems to have run out of ideas when it comes to barks of trees. All of them are brown, perhaps varying only in the particular shade.

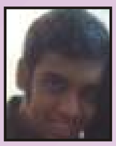
Why is this so? Nature must surely be very wise with a purpose behind the creation of coloured petals in flowers. If flowers were not so attractive, bees and butterflies would not go to them so easily to suck their nectar and cause pollination. Without pollination,how would flowers reproduces? It is their beautiful appearance that draws these flighty messengers to flowers and ensures the survival of their species. Barks of trees, on the other hand, do not have any such function. Their role is to act as a firm support for the tree without any need to look attractive. What is important is their hardness, toughness, height and width, rather than their colour. So nature has concentrated on these aspects of the bark of a tree by making it a firm and solid support.

Further, the main chemical compounds present in the bank of a tree, called tannins, are brown in colour. They lend the uniform colour to the tree's bark, the particular shade varying owing to different amount of tannin present in different trees. This is the reason why the barks of all trees are brown in colour.

An extract from the book, "I Wonder Why" (ISBN 81-7011-937-5), Pgs. 86-87, authored by Neeraja Raghavan, illustrated by Subir Roy, and published by Children's Book Trust, New Delhi

Why I Do Not Like Science

Paarth Singh



In the film, "Dead Poet's Society", Robin Williams said that there are two kinds of professions: one that sustains life and the other that shows the beauty of life. Science, I believe, belongs to the former category and I would like to be a part of the latter. However I am a part of the former since I am now studying commerce!

I decided to leave Science when I was sixteen years old. I am eighteen now, and had I to make the decision now, it would still be the same. In school, Science was like a buffet at a seven-star hotel. It all looks delicious but, when eaten, it turns out to be bland and tasteless. I would place the blame for this 'bad food' more on the cook than on the eater. Simply because, through this analogy, I want to express my opinion that science (in school) is not cooked well; it is thrown onto platters (books) and served to us - and we look at it with fascination, but when we study (eat) it, it is bland and tasteless.

These are the roots of my dislike for science. These roots have more to do with the way science is taught than with science itself.

At the high school level, Science is divided into Chemistry, Physics and Biology. The extraction of aluminum, the rectilinear propagation of light and the evolution of man just don't seem to arouse in me even a fraction of the exhilaration that the practioners of these processes (and the discoverers of these phenomena) might have experienced. My obstinate inner self refuses to accept knowledge which I cannot feel. But then, apart from literature, I cannot feel history, geography or accounts too, and yet I don't seem to dislike these subjects as much. Why then the dislike for science?

The reason is simple. Science teaches us to create - which is why I respect it. But every time it fails me because I cannot *feel* it. And isn't it human to dislike something a lot more, if you first held it in high regard and it then fails you?

I know I am being unfair because I seem to be absolving myself of (at least some of) the blame. If I respect science so much, I must work to achieve what I expect from it, because I must serve the living with the (seemingly dead) science that I learn.

As I mentioned at the outset, I want to be part of a profession which shows the beauty of life. Science, unfortunately, does not serve me that purpose, because it is overly factual and devoid of multiple perceptions. [Except for when scientists collide over whether space is loopy or straight!]

I love literature. I love entrepreneurship. As a child, I had hoped to become a scientist and cure AIDS. Today, I hope to become an entrepreneur and employ (and give a living to) those who have AIDS.

Science is not bad; it is just not good enough.

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Why I Love Chemistry

Neeraja Raghavan

Until the year that I went to Class IX, I was like any other schoolgirl - in that I hadn't the faintest idea as to what I would do in college. One day, it was literature, another, art, and yet another, medicine. Not surprisingly, the future was one big blur, which alternately, took on new forms, depending upon the current trend amongst peers.

And then, our Chemistry teacher walked into Class IX. I had heard of her eccentricities and unique traits: that she wore her sari with not a pleat out of place, she donned a lot of makeup, and that she talked while looking up at the ceiling, and indeed, she lived up to her fame in all these respects.

But what no one had ever told me was this: she was simply riveting!

She held my attention from the word go! I listened spellbound as she articulately waxed about some topic (I forget which) in Chemistry. All I recollect is that I was not the same person after my first period with her. My God, this was awesome! Her clarity was astounding. It was as if the pages of a crystal clear book unfurled before my eyes, just as the words rolled off her tongue. What a subject, man! If my mouth could water at the prospect of learning more in this fascinating field, it surely would have. Right away, I knew what I wished to do: Chemistry, Chemistry and more Chemistry. If someone could have poured it down my throat in barrels, I would cheerfully have drunk it all. In fact, ever since that day, as I would pack my bag according to the time table, the Chemistry period would seem to shine and sparkle from the time table, as if it had a light of its own. Why couldn't we have all eight periods of just Chemistry, I would plaintively muse. And on those days when we had a double period of Chemistry, I would dance my way to school.

What was so special about this teacher, you may well ask. She was clear in her communication, for one. If I listened to her once, that was enough. I got what she had to say. Then, she made the logic of the subject emerge clearly through each exposition. Chemistry was a subject that seemed so easy, when she taught it. (And she was my Chemistry teacher right until I finished school). I felt supremely confident that my Chemistry marks would soar above the other subjects in my Board (school-leaving) exam. (In fact, they didn't: amongst my five subjects, I scored the least in Chemistry).

But the precious thing was this: my performance in any test or exam did not really influence my love for this subject. For Ms. Gomez had given me something invaluable: a love for a subject that bordered on devotion. Chemistry was my first true love: and I didn't mind if my love was unrequited! I was absolutely determined to pursue the subject in college. Why, I would discover a new element: it would be named Neerajanium, and so on; Marie Curie was my role model, Ms Gomez came second.

In my final year of school, Doordarshan broadcast a television programme wherein they interviewed research scholars of Delhi University. Young men and women who were studying for a Ph.D. in Chemistry were interviewed by the TV Channel. And a more depressed bunch of youngsters would be hard to find. Their entire body language spoke of their despondency. Wilting before the camera, these drooping youngsters bemoaned their fate in having opted for a field with no career prospects. Many of them spoke sleepily of how they would be jobless after they submitted their doctoral theses.

The very next day found me at the centre of a barrage of questioning by my classmates. [All of them knew only too well how I had set my heart on doing Chemistry in college.]

“So?” they smirked. “Did you see the programme last night?'

“I did,” I replied calmly.

"And? What have you decided to do now, in college?"

"Chemistry," I replied without a pause.

"Are you mad?" They were shocked, and descended upon me like a bunch of vultures. Did I even have the faintest idea what I was embarking on? A wasted life? A life without any career prospects?

I was truly without any apprehensions whatsoever, as I calmly countered their attacks by saying: "I love the subject and that is what I wish to do."

It speaks of the intensity with which I already loved the subject that I felt not a shred of fear. After all, when one is doing what one loves, one doesn't look for any other motive, was my simple logic. Years later, when I completed a Masters' in Chemistry and decided to go in for a Ph.D. in the subject, I wrote a letter to Ms. Gomez and thanked her for sowing the seed of such a long lasting love affair.

It was only when I was later faced with a career choice that I realised she had planted more than one such seed: for, by now, it was patently clear to me that I had to be a teacher. If one teacher could impact me so: wouldn't it be wonderful if I, too, could impact a student thus?

And so it is that a dedicated teacher turned my life around: in my choice of a course for higher study, my choice of a career and in many ways, the very way I think about Chemistry and Science.

I have often been asked if this teacher impacted all her students thus: and the answer is, no, she did not. While most of her students agreed that she taught well, I was one of the few to come totally under her spell.

But I think my story's import lies in this: the power a teacher can wield, and the timelessness of her influence, even in a career choice, not to speak of the way one views the subject. Today, I can honestly testify that Chemistry is not a subject that needs memorization significantly more than any of the other sciences do. For I was taught so, and have, I hope, managed to teach so. Thank you, Ms. Gomez!

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A CASE IN STUDY

Towards a People's Education Movement - Tamil Nadu Science Forum (TNSF) and School Education

T.V. Venkateswaran

This article traces the historical evolution of TNSF's role in education from the mid-1980s to 2008. From organising a few training programmes on low-cost activities for teachers, TNSF today is set on a mission to galvanise the entire Tamil society to focus on school education.

Formative years

Tamil Nadu Science Forum (TNSF) was established in 1980 by a motley group of scientists in IIT Madras, research scholars from universities, and a few school and college teachers. In the initial years, the activities were more in the nature of expressing concerns over the deteriorating environment, the impasse in science education and concern regarding the use of science and technology for building atom bombs. Slowly and steadily, students, research scholars and teachers were attracted towards TNSF, and it became active since 1986. This group, which started out by organizing 'popular science lectures' in the city, began to take telescopes and slide shows to villages, to show people the stars! Puzzling as it may sound, even hungry and roofless villagers wanted to hear about the stars. Innate curiosity about the world and thirst for knowledge does move one and all - rich or poor.

A major flip came about in 1987 when TNSF took part in a massive national-level science popularization programme called Bharat Jan Vigyan Jatha that went around the nooks and corners of the country, with the message of 'Science for the People, Science for the Nation and Science for Discovery'. Science was seen neither as just a collection of facts nor as gee-whiz gizmos. Science was seen as a world-view, distinct from non-secular and exclusivist ones.

By then, a number of teachers from middle schools, in various parts of the State, were associated with TNSF, and a lively debate, on what science education is, ensued in TNSF. The traditional wisdom then prevailing, that emphasized on the chalk-and-talk method and advocated various tricks (like mnemonics, to 'memorize the answers efficiently'), was questioned. The question, “Can science be learned in a non-scientific way like memorizing?” and the role of experiments and investigations in learning of science, were hotly debated. Fortuitously, this was the period when, in England, a radically new method of teaching of science, later to be characterized as the 'discovery approach', of the Nuffield science teaching programme, emerged. Whether or not one could really base science teaching on experiments and activities in government schools, which often lacked even basic facilities, was a daunting dilemma. Meanwhile, TNSF was introduced to Eklavya's Hoshangabad Science Teaching Programme (then being shaped in Madhya Pradesh), which laid emphasis on experiments and activities using low-cost techniques. TNSF teachers had an exposure to the Kerala Sastra Sahitya Parishad (KSSP) which emphasized making the learning of science 'joyful'. TNSF activists and teachers were of the opinion that we should learn from both - making science learning joyful and, at the same time, activity-based, using low-cost / no-cost methods.

Around 1988, a series of teacher training camps were arranged all over Tamil Nadu, to orient middle school teachers towards various low-cost / no-cost methods. The training programmes proved successful, and more teachers were attracted towards TNSF. Though the actual impact in the formal school was limited, TNSF encouraged formation of science clubs - *Thulir Illams* - around the readership of its children's science monthly - *THULIR*. Children's Science Festivals were conducted at many places and the teachers trained in these workshops played the role of resource persons.

Learning beyond school

TNSF firmly holds the opinion that while formal school is given its due importance, one should not lose sight of the informal - out of school - arena. It is in this context that *Thulir Illams* became the main space for such interaction. The least that was taken up in *Thulir Illams* were reading and discussing *Thulir*- the monthly science magazine brought out by TNSF. Slowly, at least some children were keen to try out some of the 'Do - it - yourself' activities. Tree planting, discussion, science tours and many such activities became part of *Thulir Illams*.

Due to its prominence in working with children, TNSF became the state coordinator for the National Children's Science Congress (NCSC) programme in Tamil Nadu. The main objective of the programme was 'to stimulate scientific temperament and to learn the scientific methodology of observation, collection of data, experiment analysis, arriving at conclusions, and presenting the findings.' Groups of three to five children formed teams and undertook small research projects, for example, calculating the amount of water wasted due to leaky taps in a street, number of households that have some form of compost pit in their house, what types of birds are found in their village, what percentage of people in a locality believe in astrology, etc. The teams undertook experiments, made detailed observations, analyzed their findings and made presentations in the 'Children's Science Congresses', held subsequently.

Children's Science Festival as a vehicle for teacher sensitization

Children's Science Festival (CSF) is an out-of-school event organized with children and teachers to learn science (at times even social sciences) in a radically different mode from the way it was being taught in the school class rooms. The main objective of the CSF was to rebuild the interest of children in schools and to demonstrate, particularly to teachers and parents, that the teaching and learning processes can be made interesting, relevant, joyful and effective as well.

In essence there were two dominant foci on the activities undertaken in the CSF. One set of activities focused on the low-cost / no-cost experiments / games for teaching certain concepts in science. It was possible to prepare hydrogen gas from egg shells and lime juice without looking for costly lab equipment. In the same way, for demonstration of many physics concepts like inertia, Bernoulli's law, generation of spectrum and many more, one needed only a small contraption, easily accessible from the neighbourhood. Traditional folk games like *Pandi* (called *Staapu* in the North) could be re-worked to teach Tamil grammar, and so on. Use of role play, puppets and many other contraptions make the teaching-learning process meaningful and joyful. All these activities were hands-on, practical and simple to do and experiment with.

On the other hand, TNSF also tried to integrate various areas of knowledge/discipline and see the world around us in a scientific perspective, using an integrated approach. Science in the kitchen, for example, looked at the activity of cooking and linked maths (measurements/ratios), hygiene (cleanliness), nutrition, chemistry (cooking), energy (use of different stoves and cooking practices), physics and technology (various gadgets like the knife used in cooking). It did not stop there; science in the kitchen also raised issues such as: Who cooks? Why is it only women who are enslaved in the drudgery of cooking? What is the status of the kitchen space (where women spend most of their day) in comparison to other parts of the house (say drawing room, where we spend very little time)? Other such social dimensions were also integrated.

TNSF considers that it is important to critique the use of science and technology and underscore the need for social change. This objective was addressed in two ways. Firstly, the very way in which CSF was organised demanded that children from various socio-economic and cultural backgrounds intermingled. Thus they were able to see a new 'social reality' far beyond their daily experience. The Guest-Host system of the CSF played the key role in it. The guest children are hosted by the local students in their respective houses for the period of the festival. It is through this close interaction that both the guest and host children are able to learn about each other. They may belong to two different castes, religions, or socio-economic classes; but as they stay together they develop friendship and learn to respect and care for each other. The guest-host system can be an important tool for forging harmony and opening one's eyes to see the 'other'.

'Science' in the parlance of TNSF includes all areas of enquiry that are scientific. Thus, social sciences too form a part of CSF. In fact, in the recent years, TNSF has been trying to organize special 'social science festivals' which take up themes like caste, religion, money, democracy, food, housing, habits and customs, etc., and explore them in a scientific way. While TNSF has faith in the activity-based pedagogy, it also holds the commitment to social critique as crucial.

TNSF came up with many teacher hand books/teacher manuals that contained activities, games and worksheets. The work also generated pressure on the government. Slowly the material developed by TNSF seeped into the official textbooks and educational system. The quip, 'I hear I forget, I see I remember, I do I understand' epitomized the dominant perspective of TNSF during this period.

Joy of Learning and child-centered pedagogy

With the advent of the mid-day meal scheme, in Tamil Nadu, enrollment in schools started showing a very favourable trend. However, the drop-out rate was indeed alarming! Why does drop-out occur in such a large number ? The then prevailing common sense notion was that children of the poor go to work to earn a living - that is child labour.

Indeed child labour is an issue. Yet a study in 1991 conducted by a research team showed that, "In villages where there are no organized avenues of child labour, most of the drop-outs at primary level occur due to a combination of children's disinterest in school, their academic failure and lack of parental monitoring.".

'Joy of Learning' therefore meant not only making the classroom lively and making science learning interesting, but also became a tool to retain children in school and prevent drop-out. 'Joy' in learning was therefore understood to be, not merely the 'glee' of making hydrogen gas, nor as the 'fun' one has while doing a role play. It was now seen as something deeper - the joy and exhilaration that one feels 'discovering' for oneself and making sense of the world around. Achievement of skills, of being able to read, write and do arithmetic, is paramount to retain the interest of children. It was clear that one could not delink the universalisation of elementary education from achievement in school and learning levels. Child-centred pedagogy thus became visible in the activities of TNSF.

Rooting the reform

> *"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."*
> *-William Bragg*

While the early forays of TNSF into the education sector was limited to sensitizing the teachers in use of low-cost/no-cost experiments, since 1990s, TNSF has been playing a key role in increasing access, improving quality, introducing child-centered and activity-based pedagogy, community mobilization, etc. Teachers, children and school administration are some important players. So are parents, community (civil society), state educational officials, teachers unions, international agencies like UNICEF, educationists, and other NGOs.

It is in this context that TNSF has been organizing educational conventions as a platform for dialogue and debate amongst various actors. It is only by such debates in the public sphere that a fruitful, viable action could emerge. Thus any reform should not be pushed from above, but built by discussion and debate, with participation of every player involved in education. It is imperative that various actors are given a space in the public sphere and viable action forged.

Miles to go

Despite best efforts, TNSF is still foxed about many things related to education. From the early years, TNSF has been critiquing the examination system that emphasizes memorization and speed. The exams as we know today, are not able to assess the progress of the child in acquiring knowledge nor assess the process of teaching-learning. TNSF is as unsuccessful as many other educational organisations with regard to offering viable and practicable alternative modes for process assessments.

Most of the activities of TNSF are related to pedagogy; development of tools for activity-based, child-centered teaching-learning materials. Efforts towards curriculum development have been very little. There appears to be an assumption that the same, uniform curriculum would fit across the country/state; socio-economic background and cultural specificity do not seem to matter. Curriculum, especially from the viewpoint of a socially and economically disadvantaged child, is yet another area quite unexplored by TNSF.

Like most progressive educationists, TNSF has been advocating education, at least primary education, in the child's mother tongue. English language teaching-learning had always received little or no attention. However, in recent years, various Dalit activists have been demanding quality English language teaching to children of disadvantaged sections, especially as it provides social mobility. The need to re-examine the issue of language still remains to be addressed.

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FOUNDATION EXPERIENCE

Celebrating Science: The Science Mela

Umashankar Periodi

One could hardly recognize the school on D-Day! With more than 2000 people gathered, the school grounds draped in a colorful *shamiana*, numerous children decked vibrantly, the atmosphere was no less than that during a village *jathre* (fair), bustling with activity! This was the day of the Science Mela at Sathyampete Higher Primary School, in Shorapur block of Karnataka.

The Background

The Science Melas that are being facilitated in a number of schools across Shorapur block, are part of the Child Friendly School Program, a joint initiative of Government of Karnataka and Azim Premji Foundation.

The Child Friendly School Initiative (CFSI) is an experiment to demonstrate a process of providing quality education, in a sustained and child-friendly manner, in partnership with all stakeholders, by building capacity and accountability in the system. The program started in 2004, in Shorapur block of Yadagir educational district of North-East Karnataka. The initiative covers all the 336 government primary schools of the Shorapur block.

The program interventions deal with issues within the classroom, school and community. In-school interventions provide support to curriculum implementation, the teacher, the teaching-learning process, and improvement of the school and classroom environment. The program seeks to support positive school-community interface to ensure effective involvement and participation of the community.

Genesis of the Science Mela

The Child Friendly School Initiative is now at a crucial phase of implementation. Working more closely with the community, to involve them in the management of schools, is a major challenge. Interacting with the community has convinced us that there is very little meaningful communication between the school and the community.

A proud parent sees what his child learns in school

It is in this context that the thought of facilitating a Metric Mela emerged. The CFSI team had a very successful experience when it attempted the Metric Mela in March 2008. The implementation of this concept in Shorapur showed how such events could help address many issues involving the school-community relationship.

The Science Mela is a step forward in this direction. The team's belief is that this too, like the Metric Mela, could be a powerful catalyst for bridging the school-community divide.

Science Mela at Government Higher Primary School, Sathyampete

The Science Mela organized on 3 December, 2008, was the first Science Mela ever conducted, in the history of Shorapur. Over 2500 children, teachers and community members participated. It had nearly 70 stalls and exhibitions pertaining to science.

Objectives of Science Mela

How does the world look through a telescope?

- Develop scientific temper among children and teachers.
- Spark curiosity and interest in students towards science in everyday life.
- Provide a space for children to observe, understand, experiment and discuss various aspects of science and the things around them.
- Help children create equipment and models through

simple, low-cost materials, in order to understand the science behind these concepts.

- Help the community appreciate how understanding various scientific concepts, behind every day events, helps children develop a scientific attitude towards life.
- Enhance the participation of the community in school activities, in a festive atmosphere, where the talents and competencies of the children are showcased.
- Provide a space for children to enhance their inter-personal skills.

Preparation is the key

A serious discussion on planning for the Mela

The preparation is crucial and it was a very elaborate process too. It started with conceptualizing and visualizing the Mela and then working on each of the different experiments and models. A considerable portion of the time was spent in preparing experiments that were appropriate for the idea. For nearly three months, teachers worked hard with students to design experiments that were appropriate for effectively communicating the science behind simple phenomena to others. It was indeed challenging to actualize the conceptualized experiment in a convincing way. It required intense discussions, observation, review, revisit, rework and modification before a final product could emerge, particularly as it had to be easily understood by others.

The first round of preparatory meetings conducted with the teachers showed their interest and enthusiasm in organizing a Science Mela. Science teachers had taken on the responsibility of visualizing, conceptualizing and working on the experiments to be showcased in the Science Mela. Teachers listed around 55 experiments, exhibits and activities that could be developed with low-cost materials.

Teachers and CFSI Margadarshis conceptualizing a detailed plan

These were categorized into four sections :

1) Demonstration of experiments

2) Participation in experiments (play, do, etc.)

3) Display (exhibition)

4) Fun in science (magic, illusions, etc.)

Teachers prepared a concept note of the Science Mela and shared it with others. This helped them to not only articulate the vision, but also to take greater ownership for the event. They prepared a detailed write-up on each of the experiments under the following heads: objective, materials required, method/ process/ activity and conclusion.

Students modeling a volcano

The responsibilities were shared and the Head Teacher coordinated the entire process. The Head Teacher organized the materials required for each activity, most of which were procured locally. Students were then assigned to each activity, and they prepared the materials under the guidance of their teacher. One of the difficulties encountered in the process was that the students could not easily prepare and actualize some experiments, exactly as they had been conceptualized. Hence, some of the planned activities were revised, and some changed completely. For example, an activity on Soil Conservation had been planned with two large steel plates filled with soil. Loose mud was filled in one plate and the other plate had mud with small saplings, indicating vegetation, to prevent erosion of the soil. While pouring water into these two plates, the idea was that the loose mud will flow with the water and the roots of the plants will hold the soil in the second plate. But to the surprise of the group, the mud in


Understanding volume by actually measuring it

both the plates got washed away without any difference! This led to a lot of discussion, and it took some time for the team to understand the concept that strong roots are the binding factor here, and they replaced the loose soil of the second plate with a scraped piece of top soil which had grass with its roots intact. Processes such as these made the Science Mela more meaningful, providing as they did, plenty of learning opportunity even during the preparatory stage.

Example of an activity card

Name of the activity: Role of air in transmitting sound.

Objective: Demonstrating that air is required for transmitting sound.

Materials required: Glass beaker, mobile phone.

Explanation: In this activity, participants will be asked to stop the sound of a ringing mobile without switching it off and even without touching the mobile. This is to be done in one minute. When participants are unable to do this, students will demonstrate this.

Method: Mobile will be kept on the table. Students take a beaker or a glass which can accommodate a mobile and place the mobile inside. Students close the mouth of the beaker or glass by pressing it tightly with their hands. When they lift their hands and open the container, the sound is heard again. But when they press it tightly, the sound is not heard.

Conclusion: Sound is transmitted through the air. Air is the medium of transmission of sound.

Conclusion

Participation in the preparation of the Mela, by teachers from other schools, was a very important part of this collective and collaborative effort. The School Development and Management Committee (SDMC) played a major role in ensuring the success of the Mela. A lot of materials were mobilized from nearby schools, high schools and colleges. An important learning imbibed by the team was that the process of preparation was very enriching in itself, and hence the process was viewed as even more important than the event.


Child engrossed in showing a community leader where we live on this planet

It was indeed a sight to see adults becoming kids once again! A fresh liveliness pervaded the school, which was the hub of the village, on that day. Children took on the role of self-confident, independent individuals, completely responsible for the task at hand. There was a sense of pride not only in the children, but also in the eyes of their parents and teachers, who saw their children displaying commendable behavior, knowledge and skill.

It would be appropriate to conclude with the following words of Arathi, Assistant Teacher, Higher Primary School, Sathyampete :

"The process of preparation for the Science Mela has encouraged children to raise questions, in an informal and friendly atmosphere. I am sure that this culture of questioning will encourage a spirit of enquiry among children, which will be expressed within the classroom as well."

Umashankar Periodi is Head, Child-Friendly School Initiative, Azim Premji Foundation. He has over twenty-five years experience in the development sector. He has contributed extensively to the National Literacy Mission as well as towards tribal education in BR Hills, Karnataka. He is also the President of Karnataka State Trainers' Collective. He can be contacted at periodi@azimpremjifoundation.org

TEACHERS' RESOURCE BAG

Some Resource Books that Help make Science Fun

1 The Third Book of Experiments, Leonard De Vries, Carousel Books

2 Science Works, Ontario Science Centre, Ontario

3 Toying Around with Science, Bob Friedhoffer, Franklin Watts, New York

4 The Science Explorer, P. Murphy, E. Klages, L. Shore, An Owl Book

5 700 Science Experiments for Everyone, Compiled by UNESCO, Doubleday

6 100 Amazing Science Fair Projects, Glen Vecchione, Goodwill Publishing House, New Delhi

7 365 Simple Science Experiments with Everyday Materials, Richard Churchill, Sterling Publishers

8 The Book of Experiments, Leonard De Vries, Carousel

9 Joy of Learning, (Standards 3 to 5), Center for Environmental Education, Ahmedabad, India

10 Experiments for You, John Tollyfield, Evans Brothers, London

11 How to Turn Water Upside-Down, Ralph Levinson, Beaver Books, London

12 Experiments with Everyday Objects, Kevin Goldstein-Jachson, Granada Publishing, New York

13 Simple Science Experiments, Batstord, Hans Jurgen Prees

14 Let's Discover Science, David Horsburgh, Oxford University Press

15 Chai Ki Pyali Mein Paheli, Partho Ghosh & Dipandar Home (Hindi) National Book Trust, New Delhi 110016

16 UNESCO Source book for Science in the Primary School, Harlen & Elstgeest, National Book Trust, New Delhi 110016

17 Soap Bubbles, C.V. Boys, (Eng/Hin), Vigyan Prasar, C-24 Qutub Institutional Area, New Delhi 110016

18 The Chemical History of a Candle, Michael Faraday (Eng/Hin), Vigyan Prasar, New Delhi, info@Vigyanprasar.gov.in

19 Science in Everyday Life, J.B.S. Haldane, Vigyan Prasar, New Delhi, info@Vigyanprasar.gov.in

20 VSO Science Teacher's Handbook, Andy Byers, Ann Childs, Chris Lane (Hindi) Eklavya, Bhopal, pitara@eklavya.in

21 Environment & Self-Reliance, Yona Friedman, Eda Schaur (Eng/Hin), Vigyan Prasar, New Delhi

22 Energy & Self-Reliance, Yona Friedman, (Eng/Hin) Vigyan Prasar, New Delhi, info@vigyanprasar.gov.in

23 The Story of Physics, T. Pammanabhan (Eng/Hin) Vigyan Prasar, New Delhi,info@vigyanprasar.gov.in

24 On the Various Forces of Nature, Michael Faraday, Vigyan Prasar, New Delhi, info@vigyanprasar.gov.in

25 The Insect World of J. Henri Fabre, Vigyan Prasar, New Delhi, info@vigyanprasar.gov.in

26 The Autobiography of Charles Darwin, Vigyan Prasar, New Delhi, info@vigyanprasar.gov.in

27 The Bicycle Story, Vijay Gupta, Vigyan Prasar, New Delhi, info@vigyanprasar.gov.in

28 Aakash Darshan Atlas, Gopal Ramchandra Paranjpe, NCERT, Sri Aurobindo Marg, New Delhi 110016

29 Preparation for Understanding, Keith Warren, illus. by Julia Warren, UNESCO

30 Resonance Journal of Science Education, Indian Academy of Sciences

Courtesy : Aha! Activities, Eklavya, Bhopal

Websites & E-Resources for Middle and Primary School Science

1. LET'S DISCOVER SCIENCE PART I By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/david1.pdf)
2. LET'S DISCOVER SCIENCE PART II By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/david2.pdf)
3. LET'S DISCOVER SCIENCE PART III By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/david3.pdf)
4. LET'S DISCOVER SCIENCE PART IV By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/david4.pdf)
5. LET'S DISCOVER SCIENCE PART V By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/david5.pdf)
6. LEARNING ABOUT LIVING PART ONE By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/D6.pdf)
7. LEARNING ABOUT LIVING PART THREE By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/D7.pdf)
8. THINKING AND DOING By David Horsburgh (out of print but downloadable as a pdf file from the link: http://vidyaonline.org/arvindgupta/ thinkanddo.pdf)
9. SMALL SCIENCE for Classes I to V (with the accompanying Workbooks and Teachers' Books) Homi Bhabha Centre for Science Education,TIFR, Mumbai. http://www.hbcse.tifr.res.in/smallscience.
10. http://www.arvindguptatoys.com/ contains an enormous list of books on enlivening science learning, rated by Arvind Gupta. Many of them can be downloaded for free.
11. LOW COST EQUIPMENT FOR SCIENCE AND TECHNOLOGY EDUCATION - Vol. 1 - Compiled by UNESCO http://unesdoc.unesco.org/images/0010/001023/102321eb.pdf Provides ideas on how to make school science equipment using inexpensive materials.
12. LOW COST EQUIPMENT FOR SCIENCE AND TECHNOLOGY EDUCATION - Vol. 2 - Compiled by UNESCO - http://unesdoc.unesco.org/images/0007/000728/072808eb.pdf Provides ideas on how to make school science equipment using inexpensive materials.
13. http://www.exploratorium.edu/ is a fascinating website with tons of resources, activities and continuous updating to reflect the latest developments in the field.
14. http://www.johnkyrk.com/ has links to animations of cell structure, cell biology, DNA, etc.
15. http://www.bbc.co.uk/schools/scienceclips/ages/8_9/circuits_conductors_fs.shtml has an interactive tutorial on conductors.
16. http://www.primaryschool.com.au/science results.php?kla=Science%20and%20Technology&unit=Switched%20On has links to several interactive lessons like the one above.
17. http://www.juliantrubin.com/bigten/pathdiscovery.html allows the user to simulate online repetitions of famous experiments or inventions.
18. http://www.freeindia.org/biographies/greatscientists/has biographies of Indian scientists.
19. http://www-gap.dcs.st and.ac.uk/~history/Indexes/Indians.html has info on ancient Indian mathematicians.
20. http://www.calcuttaweb.com/people/snbose.shtml has some more biographies of Indian scientists.

21. http://www.shodor.org/succeed/curriculum/FOR/observation.html contains an interactive module to test one's observation powers.

22. http://www.science-class.net/PowerPoints/NOS_Test_Review.ppt contains a PPT that talks of the nature of science.

23. http://www.science-class.net/PowerPoints/NOS_Test_ReviewGT.ppt contains a second such PPT.

24. http://www.scienceclass.net/Teachers_Lessons.htm contains many valuable links to lessons on science topics for middle school level.

25. http://www.science-class.net/TAKS/taks.htm has many links to PPTs that elaborate specific concepts for middle school.

26. http://teachers.net/lessons/posts/1228.html (a website leading from http://www.curriki.org/xwiki/bin/view/Coll_rmlucas/LabClassificationofShoes?bc=;Coll_rmlucas.10 Classification) describes an activity wherein children have to classify shoes, so as to understand the importance of classification. (Useful in all branches of science, particularly chemistry and biology.)

27. http://www.encyclomedia.com/video-arctic_food_chain.html has a video on the arctic food chain.

28. http://www.kbears.com/ocean/octopus/index.html has a presentation and info on the octopus.

29. http://magma.nationalgeographic.com/ngexplorer/0309/articles/mainarticle.html contains rich info on underwater life.

30. http://www.seaworld.org/animal-info has a plethora of links and info on animals.

31. http://www.seaworld.org/fun-zone/coloring-books/pdf/emp-penguin.pdf has a colouring page for kids to have fun, when learning about animals.

32. http://kids.nationalgeographic.com/Animals/CreatureFeature/ is a superb site where you can click on an animal to find out more about it. The 'more' includes facts, a video with sound, a map of places where it can be found, etc.

33. Resources for Teaching Middle School Science (1998) - http://books.nap.edu/catalog.php?record_id=5774 (ISBN 0309057817) National Science Resources Center of the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the Smithsonian Institution

34. Resources for Teaching Elementary School Science (1996) - http://books.nap.edu/catalog.php?record_id=4966 (ISBN 0309052939) National Science Resources Center of the National Academy of Sciences and the Smithsonian Institution

35. http://www.exploratorium.edu/explore/handson.html contains many online as well as hands on activities for children of this age group and younger.

36. http://fi.edu/tfi/activity/act-summ.html contains many online as well as hands on activities for children of this age group and younger.

37. http://www.bbc.co.uk/schools/scienceclips/ages/10_11/science_10_11.shtml contains activities listed alphabetically, topic wise.

38. http://www.bbc.co.uk/schools/scienceclips/ages/9_10/changing_sounds.shtml contains simple sorting and tabulation exercises for Class V and below.

39. http://www.bbc.co.uk/schools/scienceclips ages/10_11/forces_action.shtml contains more complicated tabulation and interpretation exercises for Class VI/VII.

40. http://www.bbc.co.uk/schools/teachers/ks4/bitesize_chemistry.shtml contains chemistry assessment worksheets for Classes VIII and IX.

41. http://www.bbc.co.uk/schools/gcsebitesize/chemistry/classifyingmaterials/ contains exercises for assessing classification of matter, atomic structure, bonding and formulae/equations for Class VIII and above.

42. http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/ has some thinking-type questions for Class VIII and above.

43. http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/ has excellent questions for Classes VII, VIII and above.

44. http://cse.edc.org/products/onlinecurr/catalog.asp has an online catalogue of web-based resources for middle and elementary school science.

45. http://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=491 has a beautiful animation of the photoelectric effect, can be shown to Class VIII.

46. http://www.explorelearning.com has a number of interactive simulations to learn science, appropriate for this age group.

47. http://cse.edc.org/products/onlinecurr/WBMISearchResults.asp has a complete list of topics and the modules available therein, for students of this age group and a little older as well.

48. http://www.blupete.com/Literature/Biographies/Science/Scients.htm has links to biographies of scientists.

49. http://www.juliantrubin.com/bigten/pathdiscovery.html is a website with a collection of links for discovery and invention.

50. http://www.fordham.edu/Halsall/science/sciencesbook.html is an Internet Sourcebook for the History of Science.

51. http://www.middleschoolscience.com/tunefork.htm has a good activity for learning about the tuning fork and sound vibrations, suitable for Classes VII and VIII.

52. http://www.pbs.org/benfranklin/exp_shocking.html has a lovely interactive simulation of the kite experiment performed by Benjamin Franklin.

53. http://www.pbs.org/teachers/sciencetech/ has grade-wise, topic-wise lesson plans for middle and primary school science teaching.

54. http://www.learner.org/resources/series90.html has a set of videos on the science of teaching science.

55. http://www.outlookindia.com/scriptur11w2.asp?act=sign&url=/full.asp?fodname=20050328&fname=Science&sid=1 has Nobel Prize-Winning Science Discoveries made palatable for children.

56. http://www.teachernet.gov.uk/teachingandlearning/subjects/science/science_teaching_resources/ provides links to a number of e-teaching learning resources for primary science.

57. http://www.firstscience.com/home/ is a leading online popular science magazine featuring articles on important breakthroughs, the latest science news, video clips, blogs, poems, facts, games and a whole lot more science-related content.

58. Chakmak: Science magazine for children http://www.eklavya.in/go/index.php?option=com_content&task=category&sectionid=13&id=57&Itemid=84

59. Sandarbh: A resource bank for teachers http://www.eklavya.in/go/index.php?option=com_content&task=category&sectionid=13&id=51&Itemid=72

60. Srote: Science and Technology features - http://www.eklavya.in/go/index.php?option=com_content&task=category&sectionid=13&id=56&Itemid=81

61. http://www.gobartimes.org/20090315/20090315.asp is a bi-monthly children's magazine highlighting news and views on environment and development through comic strips, cartoons, quizzes, essay competitions and interactive pages. It also serves as a useful teaching aid in classroomsfor teachers.

62. http://edugreen.teri.res.in/index.asp is a website for children that makes environmental learning fun

63. http://www.nuffieldcurriculumcentre.org/go/Default.html provides links to websites of various science projects that undertake to enliven science teaching

64. http://www.exploratorium.edu/ifi/resources/workshops/teachingforconcept.html provides a link to the paper "Teaching for Conceptual Change: Confronting Children's Experience; Watson, Bruce and Richard Kopnicek; Phi Delta Kappan, May 1990".

Some Books containing Activities & Games in Science

Class	Topics
	Little Toys, Arvind Gupta; National Book Trust, New Delhi
V	Trees (Pg.33) [See also "My Book of Trees" by Nimret Handa], Area (Pg. 37), Volume (Pg.37)
VI	Area (Pg. 37), Volume (Pg. 37), Colour (Pg. 33), Pressure (Pg. 9), Siphon Action (Pg. 11), Pump (Pg. 13), Wind Energy (Pg.19), Sound/Vibration (Pg.15)
VII	Pressure (Pg. 9), Siphon Action (Pg. 11), Pump (Pg. 13), Wind Energy (Pg.19), Sound/Vibration (Pg.15), Static Electricity (Pg. 47), Friction & Gravity (Pg.31), Conversion of Potential Energy into Kinetic (Pg. 25), How Engines Work (Pg.21), Gear Wheel Motion, Circular and Linear Motion (Pg.17), Archimedes Principle (Pg.53)
VIII	Conversion of Potential Energy into Kinetic (Pg. 25), How Engines Work (Pg.21), Gear Wheel Motion, Circular and Linear Motion (Pg.17), Archimedes Principle (Pg.53), To understand flight (Pg. 41)
	Ten Little Fingers, Arvind Gupta; National Book Trust, New Delhi
V	Volume (Pg. 22), Weight (Pg. 13), Shape (Pg 11), Size (Pg. 12)
VI	Volume (Pg. 22), Pulleys (Pg. 25)
VII	Pulleys (Pg. 25)
	Toy Bag, Arvind Gupta; Eklavya, Bhopal
VII	Centripetal Force (Pg. 13)
	Predator: The Forest Food Chain Game; Ampersand Press, Washington
V	Food Chain (to be adapted to Indian animals and vegetation)
	Science Fair Projects Energy, Bob Bonnet & Dan Keen; SCHOLASTIC
V and VI	Energy

Class	Topics
Understanding Science - Level Two, Peter Clutterbuck; SCHOLASTIC	
V	Plants, Animals, Food Chain, Seeds, Vertebrates/Invertibrates, Habitats
VI	Gases, Liquids, States of Matter, Force & Motion
VII	Sound, Light, Energy, Digestive System, Respiratory System
Super Science Crosswords, Katherine Burkett; SCHOLASTIC	
V	Plants, Seeds, Vertebrates
Penguins Swim but Don't get wet, Melvin & Gilda Berger; SCHOLASTIC	
V	Animals
The Usborne Internet Linked Library of Science: Earth and Space, Howell, Rogers & Henderson; SCHOLASTIC	
VI	Earth Science
The Usborne Big Book of Experiments; SCHOLASTIC	
V	Plants & Animals
VI	States of Matter, Gases, Expansion & Contraction, Light & Sound, Plants & Animals, Forces & Motion
VII	Acids & Alkalis, Everyday Chemicals, Light & Sound, Electricity and Magnetism, Forces & Motion
VIII	Electricity and Magnetism
My Book of Trees, Nimret Handa; SCHOLASTIC	
V	Trees
Scholastic Encyclopedia of Animals, Laurence Pringle	
V and VI	Animals
The Illustrated Encyclopedia of Science; Pentagon Press	
VI and VII	Changes, Everyday Materials, Earth Science
The Illustrated Encyclopedia of Earth; Pentagon Press	
VI and VII	Animals, Earth Science
Kingfisher Young Knowledge Materials: Liquids, Solids, Gases; Clive Gifford	
VI	Everyday Materials, Changes
100 things you should know about Science, Steve Parker; Miles Kelley Publishing	
VI	Forces & Motion, Light & Sound, Everyday Materials
Sharing Nature with Children, Joseph Bharat Cornell	
V and VI	Food Chain, Plants, Animals, Birds
Simple Nature Experiments with Everyday Materials, Anthony D Fredericks	
V and VI	Plants, Animals, Birds, Insects

Some Important Organisations in Science Education

S.no.	Name of the Organisation	Contact Details
1.	Agastya International Foundation	*Address :* Kataria House, 219 Kamaraj Road, Bangalore - 560042 *Phone :* 080-25548913-16 *Website :* www.agastya.org *E-Mail :* Maagastya@vsnl.com
2	Avehi-Abacus Project	*Address :* Third floor, K.K. Marg Municipal School, Saat Rasta, Mahalaxmi, Mumbai- 400 011 *Phone :* (022)2307 5231, (022)2305 2790 *Website :* http://avehiabacus.org *E-mail :* avcab@vsnl.com
3	Bangalore Association for Science Education (BASE)	*Address :* Jawaharlal Nehru Planetarium, Sri. T. Chowdaiah Road, High Grounds, Bangalore-560001 *Phone :* 080-22266084, 22203234 *Website :* http://www.taralaya.org *E-Mail :* taralaya@vsnl.com
4	Bharat Gyan Vigyan Samiti/ Indian Organisation for Learning and Science	*Address :* Basement of Y.W.A. Hostel No. II, Avenue - 21, G-Block, Saket, New Delhi-110 017. *Phone :* 011-2656 9943 *Website :* http://www.bgvs.org *E-Mail :* bgvs_delhi@yahoo.co.in, bgvsdelhi@gmail.com
5	Center for Environment Education	*Address :* Nehru Foundation for Development, Thaltej Tekra, Ahmedabad - 380 054, Gujarat *Phone :* 079-26858002 *Website :* http://www.ceeindia.org *E-Mail :* cee@ceeindia.org
6	Center for Science and Environment	*Address :* 41, Tughlakabad Institutional Area, New Delhi-110062, INDIA *Phone :* 011-29955124/25, 29956394, 29956401, 29956399 *Website :* http://www.cseindia.org *E-Mail :* cse@cseindia.org
7	C.P.R. Environmental Education Centre (CPREEC)	*Address :* The C. P. Ramaswami Aiyar Foundation No.1, Eldams Road, Alwarpet, Chennai Tamilnadu, India. PIN - 600 018 *Phone :* 044-24337023, 24346526, 24349366 *Website :* www.cpreec.org *E-Mail :* cpreec@vsnl.com, ecoheritage_cpreec@vsnl.net
8	Eklavya	*Address :* E-10, BDA Colony, Shankar Nagar, Shivaji Nagar, Bhopal - 462 016 Madhya Pradesh, India *Phone :* 0755-267 1017,255 1109 *Website :* http://eklavya.in
9	Eklavya Institute of Teacher Education (EI)	*Address :* Eklavya Education Foundation, Core House, Off. C.G.Road, Ellisbridge, Ahmedabad-6 *Phone :* 079-26461629 *Website :* www.eklavya.org *E-mail :* eklavya@ekalavya.org
10	Homi Bhabha Centre for Science Education	*Address :* Mr. H C Pradhan, Tata Institute of Fundamental Research, V.N. Purav Marg, Mankhurd, Mumbai, 400088 *Phone :* 022-25554712, 25580036 *Website :* www.hbcse.tifr.res.in *E-Mail :* postmaster@hbcse.tifr.res.in
11	Indian Science Congress Association	*Address :* 14, Dr. Biresh Guha Street, Kolkata - 17 *Phone :* 033-2287 4530 *Website :* http://sciencecongress.nic.in *E-mail :* iscacal@vsnl.net

S.no.	Name of the Organisation	Contact Details
12	Kalpavriksh Environment Action Group	*Address :* 134, Tower 10, Supreme Enclave, Mayur Vihar, Phase 1, Delhi 110 09 *Phone :* 011-22753714 *Website :* http://www.kalpavriksh.org
13	Kerala Sastra Sahitya Parishad	*Address :* Parishad Bhavan, Chalappuram PO, Kozhikkode - 673 002, Kerala, India *Phone :* 0495-2701919, 9447038195 *Website :* http://www.kssp.org.in *E-Mail :* gskssp@gmail.com
14	National Council for Science & Technology Communication (NCSTC)	*Address :* Department of Science & Technology Technology Bhavan, New Mehrauli Road, New Delhi-11001 *Phone :* 011-26567373, 26962819 *Website :* www.dst.gov.in *E-Mail :* dstinfo at nic dot in
15	Navanirmiti	*Address :* Navnirmiti, 301,302,303, 3rd floor, A wing, Priyadarshani Apartment, Padmavati Road, IIT Market Gate, Powai, Mumbai- 400 076. *Phone ;* 022-25773215, 25786520 *Website :* www.navnirmiti.org *E-mail* : contact@navnirmiti.org
16	Nuffield Foundation	*Address :* 28 Bedford Square London WC1B 3JS *Phone :* 020 7631 0566, 020 7580 7434 *Website :* www.nuffieldfoundation.org *E-mail :* info@nuffieldfoundation.org
17	Rajiv Gandhi Foundation	*Address :* Jawahar Bhawan, Dr. Rajendra, Prasad Road New Delhi - 110 001, INDIA *Phone :* 011-23755117, 23312456 *Website :* www.rgfindia.org *E-mail :* info@rgfindia.org
18	State Institute of science education	*Address :* S.I.S.E (Rajya Vigyan Sansthan), P.S.M Campus, Jabalpur, M.P. 482001 *Phone :* 0761-2625776 *Website :* http://sisejbp.nic.in
19	Sutradhar	*Address :* 59/1, 3rd Cross, 10th A Main, Indiranagar 2 Stage, Bangalore 560038. *Phone :* 080-25288545,25215191 *Website :* www.sutradhar.com *E-Mail :* sutra@vsnl.com
20	Tamil Nadu Science Forum	*Address :* Balaji Sampath, C2 Ratna Apts. AH 250, Shanti Colony, Annanagar, Chennai-600040, TAMIL NADU *Phone :* 044-26213638 *Website :* bsampath@eng.umd.edu
21	Tamil Nadu State Council for for Science and Technology,	*Address :* Directorate of Technical Education Campus, Chennai 25 *Phone :* 022-22301428 *Website :* www.tanscst.org *E-mail :* enquiry@tnscst.org
22	Vidya Bhawan Society	*Address :* Fatehpura, Udaipur, Rajasthan 313001 *Phone :* 0294 2450911 *Website :* http://www.vidyabhawan.org *E-Mail :* info@vidyabhawan.org, vbsudr@yahoo.com
23	Vikram A Sarabhai Community Science Center	*Address :* Opp. Gujarat University, Navrangpura, Ahmedabad - 380 009 *Phone :* 079-26302085,26302914 *Website :* www.vascsc.org *E-Mail :* info@vascsc.org

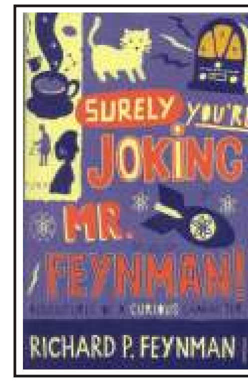
BOOK REVIEW

"Surely You're Joking, Mr Feynman!" - Adventures of a Curious Character

By Richard P Feynman

Vintage Books, London (1992) : 350 pages

A Review by Neeraja Raghavan



Wouldn't you expect a budding scientist to do more than fry potatoes in his lab? Here is a book that promises to give you many more such surprises. I have read this book at least three times and enjoyed it as much, if not more, at each reading.

For one thing, it shakes the stereotypical image of an absent minded (and boring) scientist, pottering about his dingy laboratory, full of strange mutterings. Indeed, it makes one wonder if there are many who could be more sparkling and irresistible in their overflowing wit, intelligence and verve for living!

Feynman's former student Albert R Hibbs captures the essence of the book in his pithy introduction: "...he talked to us about physics, his diagrams and equations helping us to share his understanding. It was no secret joke that brought the smile and sparkle in his eye, it was physics. The joy of physics! The joy was contagious. We are fortunate who caught that infection. Now here is your opportunity to be exposed to the joy of life in the style of Feynman."

Yes, the joy of life, too, is as contagious when one reads this book. I have risen from my desk bubbling with energy, each time I have sat down to read this book.

As a boy, the most remarkable facet of this future Nobel Laureate is his interest in many things around him and his incessant energy to investigate most of them. For instance, he loved falling off to sleep listening to the radio, and that spurred him to start building his own. One day, he discovered (to his amazement) that he could tune into a radio channel that was being broadcast from Schenectady an hour before it was broadcast in New York (where he lived). So this mischievous lad pretended to his friends that he had some predictive powers, as they lolled about listening to a radio play and he 'uncannily' guessed the next scene! Well, one thing led to another (and this happens all the time in this delightful book) and Feynman became the neighbourhood radio handyman even though he was still just a boy. People constantly called him up to fix their radios and were amazed at how he did it 'by thinking'.

> *"When I was about eleven or twelve I set up a lab in my house. It consisted of an old wooden packing box that I put shelves in. I had a heater, and I'd put in fat and cook French-fried potatoes all the time."*
>
> *- Richard Feynman*

In his own words: "Once I get on a puzzle, I can't get off." Feynman calls it his 'puzzle drive'. He couldn't resist cracking any sort of puzzle: be it Mayan hieroglyphics, or trying to open safes or solving a geometry puzzle (which a senior boy brought him from the advanced Math class)!

"During high school every puzzle that was known to man must have come to me. Every damn, crazy conundrum that people had invented, I knew."

If you can hear a mind tick, while reading a book, then this is that book. Whirring away like the wings of a helicopter, his mind buzzes from one problem to another, descends gracefully on one that appeals to him, hovers around it until it is solved, and then takes off to the next one: however unrelated it may be.

To come into such close contact with genius such as this: rare, indeed, are such opportunities!

When faced with a time-bound problem that could not possibly be conventionally solved in the limited time allotted, Feynman would ask himself: "Is there a way to *see* it?" I was particularly struck by this question. The leap that it makes out of the typical 'thinking in a box' framework stems both from the self-confidence as well as the utter enjoyment that this boy experienced in cracking puzzles. Most ordinary folk would simply be so crippled by the impossibility of solving it in a straightforward manner in so short a time, that they would hardly be in a position to think of anything else.

Is this, then, the line between a genius's mind and an ordinary one, one wonders?

Cutting string beans, chopping potatoes, answering the telephone as a desk clerk: Feynman attempted innovating at each of these odd jobs to make them more efficient. Brilliant as his ideas were, he admits: "I learned here that innovation is a very difficult thing in the real world." Obviously, though, he didn't stop trying!

When Feynman was a boy, his father and he would watch the birds together. The manner in which he was gently led to observe keenly - rather than merely name the bird and dash off - is extremely revealing. [The relevant portion has been captured above in the box.]

'See that bird?' my Dad would say. 'It's a Spencer's warbler. (I knew he didn't know the real name.) 'Well, in Italian, it's a Chutto Lapittida. In Portuguese, it's a Bom da Peida. In Chinese it's a Chung-long-tah, and in Japanese it's a Katano Takeda. You can know the name of the bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird. You'll only know about humans in different places, and what they call the bird. So let's look at the birds and see what it's doing - that's what counts!

- Richard Feynman, about how his father and he would watch birds together.

About the most beautiful extract in the book is his description of an experiment that he conducted with ants, while in his dormitory at Princeton University. Not only does it make for fascinating reading, it delineates (perhaps like no other story in the book does) how scientific method, when applied to a simple everyday problem can help solve it!

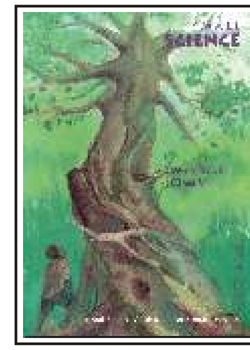
It may well be said that you are

- most fortunate if you have attended Feynman's Lectures in Physics,
- somewhat less fortunate if you have read Feynman's Lectures in Physics,
- rather unfortunate if you have only read his memoirs and
- singularly unfortunate if you haven't even read his memoirs!

So why wait? Just grab a copy and start!

Neeraja Raghavan is Consultant, Academics and Pedagogy, Azim Premji Foundation, Bangalore. She can be contacted at neeraja@azimpremjifoundation.org

Small Science Series: Textbooks, Workbooks and Teachers' Books for Classes I to V



Authors of the books:

Class 1 and 2 - Jayashree Ramadas, Aisha Kawalkar & Sindhu Mathai

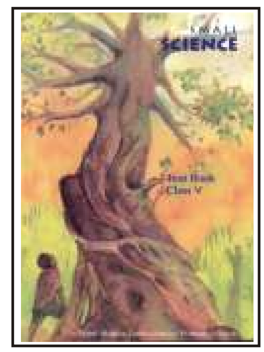
Class 3 and 4 -Jayashree Ramdas

Class 5 - Jyotsna Vijapurkar

Published by :

Homi Bhabha Centre for Science Education

Tata Institute of Fundamental Research, Mumbai



A Review by Uma Harikumar

Efforts in curriculum reform and innovations have been in effect over the decades and significant progress has been made in that direction. However, the overall deterioration of the system, due to extraneous factors, has obscured these gains. There exists a large gap between the generally agreed upon objectives of the curriculum and their actual translation into textbooks and teaching practices. The Homi Bhabha Curriculum and the Small Science Series of books (textbooks, workbooks and teachers' books) is an effort to bridge this gap. The curriculum aims to make the students develop a lively curiosity about the world around them, with a will to unravel answers through observations and enquiry. It's purpose is to ignite the minds of children, kindle their curiosity and develop in them a scientific temper.

The first few years of schooling are critical in shaping the child's attitude towards learning. The experiences at this early stage decide as to how they will perceive school learning. Will they see it as passive absorption of uninteresting, unrelated information or as a quest to understand and unravel the mysteries of the world around them?

The Small Science Series is intended for children in primary school, mainly classes 1 to 5. The topics in Class 1 and 2 cover environmental studies, and Classes 3,4 and 5 are primarily concerned with science, though keeping in view the social and cultural perspectives. The topics begin with everyday experiences and immediate surroundings, for classes 1-3, moving gradually outwards. Classes 4 and 5 make interesting use of measurement concepts.

The textbooks of class 3 and 4 interweave a story about two curious children Mini and Apu, who learn a lot by doing things and asking questions. The text, which follows this narrative, encourages students to observe the world around them, seek answers to questions, and to raise their own questions.

The language is simple. There is a well-planned effort to engage the child in exploratory and hands-on activities, to acquire basic cognitive and psychomotor skills through observation, classification, inference, etc. The illustrations are very child-friendly, with a lot of stick figures and simple, straight line drawings, which convey the concept in the simplest manner possible. The illustration of the digestive path in the class 4 textbook has an adjoining diagram of a tomato being digested. I found this very relevant since a child can relate the path taken to the things she eats!

The topics are so arranged as to make the child curious about social phenomena, starting with the family and moving on to wider spaces. The textbooks as well as the workbooks maintain the interest of the child throughout the curriculum. There are things to do, as well as things to observe and come to your own conclusions about.

The books do not look at science as being only a part of the school classroom learning process; definitely not some syllabus to be completed on time! They bring a lot of the world 'outside' into the realm of the classroom, which impresses upon the learner that science is a basic part of life. Our lives are but part of a scientific process! There is ample scope for the child to relate the topics of the curriculum to her/his day-to-day life and embark on a quest for knowledge. The books and workbooks help to systematize and express clearly the rich interactive experiences with the natural world that a primary school child has and contribute to her/his learning.

The curriculum and the books move away from the notion of giving information on something to developing the skills that are needed to study science and, consequently, understand the scientific process. There is a thrust on observation and recording even in classes 1 and 2. Activities like “Observe plants, flowers, leaves, leaf margins, colour of flowers, number of petals, any other structure” are interesting. Whether it is through the growth of a plant, the weather, or the amount of rainfall, a lot of emphasis has been laid on measurement. Drawing pictures and making entries in tabular form, provide the basis for entering statistical data later.

Discussion, listening, talking, expressing opinions, finding out information from/opinions of other people, are also skills that have been addressed. It may be, for instance, finding out what to do to stop the increase of mosquitoes or asking people why they like to travel.

There are a number of questions in the books, which help develop critical thinking. For example:

Which set of sticks would you choose to make a 'H' shape?

The books also help in demystifying a few myths, and questioning prevalent superstitions. For example, it discusses the question: Do snakes really drink the milk offered?

The outcome of the planting activity in class is to infer that all cereal plants are types of grasses. I thought that was a great way to make hypotheses and inferences.

There is a lot of improvisation, making things and doing experiments: e.g. making wind vanes, percussion instruments and many, many more.

The Workbooks

The workbooks weed out the need for classwork and homework books, reducing the burden on the young shoulders! Workbooks have been created for classes 3-5. They supplement the textbook and help the child to record observations made during the experiments.

Every chapter of the unit has something to observe, something to record, something to find out, something to think about, questions to answer, comparisons to make, vocabulary enhancement through writing of poems, writing sentences about something, as well as making sentences with new words.

The assessment sheet at the beginning of each unit is very comprehensive; the teacher needs to assess the student with reference to skills of observation, design and engineering, oral language, written language, quantitative thinking, enthusiasm in doing activities, patience and concentration, independent thinking, cooperation with other students and completion of home assignments.

The Teachers' Books

The teacher's handbook is very exhaustive and has all the relevant information, given more to facilitate questions posed by curious children. There are clear guidelines given on all that has to be dealt within the classroom, as well as the assessment process. It also addresses students' alternative conceptions and methods to deal with them. Every activity has been looked into with a lot of thought, and ways of making them as interactive as possible have also been explored to a great extent. However, nothing is prescriptive and there is a lot of liberty given to the teacher to use locally available material or content. There are many interesting questions suggested, for the teacher to pose to the class and make the lesson interesting.

There is a list of books given for further reading which is invaluable to the teacher. Every topic has been dealt with in so much detail that one has to read it to believe it! They build confidence in a teacher and motivate him/her to perform better - truly a precious resource for teachers!

To create a curriculum, write textbooks, workbooks and teacher's manual is a Herculean task. The authors, Jayashree Ramdas, Jyotsna Vijapurkar and their team, have indeed undertaken this daunting task and created a very interesting series of books that perhaps every school needs to get, in order to make science classes a source of joyful learning. As Jayashree herself puts it "Small science series are books that are not be read but to be *done*!"

For more details about the books, you could visit the website:http://www.hbcse.tifr.res.in/smallscience. Full versions of the book, in Hindi and Marathi, are also downloadable from the website.

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