In my view,
teaching science is not just
teaching about the preparation of
oxygen, atomic structure, magnetic lines
of force. I believe that teaching science
is teaching how to think scientifically keeping
the superstitions far away; and teaching how to
find solutions for problems. A child learning about
water resources means not only learning the laws,
principles and technology behind digging a well,
fitting a pump and constructing a check dam, but also
realizing the blood, toil, tears and sweat behind them.
Then only children will develop an attitude that not
even a single a drop of water be wasted. They
should realize that the food in their plates is the result
of the labour of many people and start respecting
their efforts and hard work. When
taught in this way, SCIENCE becomes a
wonderful tool to deliver social justice
to one and all.

Gijubhai Badheka

Free will Education

I believe that discussion, logic and thinking are the vital organs of any philosophy. I strongly believe that truth should be strained off through rigorous observation and tangible evidence. It is not proper to accept a thing just because somebody told it or because everybody believed in it. I think that inquiry like 'Is that true?' and 'Why did it happen like this?' is the heart and soul of any theory. I strongly believe that logic and thinking are the most important and the most valuable things in our ancient Indian tradition.

I can never agree on that the process to learn how to do mathematics or how to build bridges or how to use atomic energy is education. Education is discovering our relations with nature, people, and all the living and nonliving things around us. Education is developing good understanding; education is exploration with good potential to understand – I believe in this, in word and deed. The duty of the teachers is to teach children how to put their best foot forward to have such education and to think freely, creatively and scientifically. The education we impart becomes meaningful only when teachers have such broad outlook and when they can respond compassionately to the children's needs.

Wherever there are freedom and liberty there would not be any differences in class, caste or creed, which means, in such an atmosphere, no other thing except education is regarded as valuable. There, teachers and students teach and learn helping each other in a cooperative atmosphere. Such a great professions is teaching. Nevertheless, our main problem is not how to educate children, but how to motivate teachers to do such a great profession efficiently.

Jiddu Krishnamurti

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Preface

Whichever country that gives freedom and opportunities for children to think creatively and express their ideas without any fear, there only develops a knowledge society spreading the fragrance of democracy. This is what John Dewey said in his book 'Democracy in Education.' Isn't this true? Children can think creatively only in a free and fair atmosphere. Psychologists also say, only in such an atmosphere, their sensory organs ready themselves and work best to construct knowledge from the world around them. In this regard, Sir Francis Bacon says that the creative world in the classroom will be uncovered only when what children see, do, and hear in the classroom is meaningful and related to them. I must say this is the gospel truth.

The activities conducted in school should not be one-sided, ignoring the interests and feelings of the children. One should be doubly sure of this in a science classroom, since it follows a specific method for knowledge construction. It follows social constructivism which helps children learn through observation, hypothesizing, experimentation, analysis of results and making conclusions. Only when the learning experiences in the classroom follow this path, the children will learn in a friendly atmosphere participating in them and discovering new things, as directed by section 29(2) (e) of the RTE Act – 2009. The NCF, SCF and the RTE Act have indicated that children at high school stage should learn science as Physical Science and Biological Science. Teaching science should not be reduced to giving information; it should enable children to construct knowledge by taking part in various learning situations and by interacting with teachers, peers, teaching learning material, members of the society and nature. The RTE – 2009 reiterates that the achievement of class-specific academic standards is the responsibility of the teachers and the school. The new textbooks are developed, keeping this in view, with a multiplicity of activities that facilitate the achievement of targeted academic standards.

In the present examination system, children are really gasping for breath as they are unable to cope with it. Hence, as a breath of fresh air, we introduced the new evaluation procedure, which will take them away from the rote memorization procedures and give them an opportunity to be assessed in a stress-free atmosphere. The children's physical, social and emotional development is as important as their cognitive development, so a number of experiments, field investigations, projects, quizzes, seminars, etc., were included in the science curriculum. Since the new evaluation procedure is 'Continuous Comprehensive Evaluation', it measures the children's all round development using all these activities.

By studying science, children should learn to worship nature and protect the environment. They should come up as people who respect human endeavor and who appreciate the wonders of nature. They should realize that every being and thing in nature is as valuable as s/he is and protect biodiversity. I hope you, as a science teacher, will put your best foot forward to make such beautiful people. And I am happy to present you with this handbook which, I'm sure, will help you realize the goals of teaching science at high school level.

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Science is the attempt to make the chaotic diversity of our sense experience correspond to a logically uniform system of thought.

– Albert Einstein (1879-1955)

Right to Education Act – Chapter 5

Curriculum – Evaluation Procedure

The Right to Education Act – 2009 has given clear directions/ instructions regarding curriculum and evaluation procedure. Sections 29(1), 29 (2) (e), 29 (2) (g) and section 35(1) under chapter – 5 directed that the overall development of the children should be assessed through Continuous Comprehensive Evaluation.

Section 29(1): The curriculum and evaluation procedure for elementary education shall be laid down by an academic authority (S.C.E.R.T.) to be specified by the appropriate Government, by notification

(2): The academic authority, while laying down the curriculum and the evaluation procedure under sub-section (1), shall take into consideration the following, namely:-

- Conformity with the values enshrined in the Constitution.
- All round development of the child.
- Building up child's knowledge, potentiality and talent.
- Development of physical and mental abilities to the fullest extent.
- Learning through activities, discovery and exploration in a child friendly and child-centered manner.
- Medium of instruction shall, as far as practicable, be in child's Mother tongue.
- Making the child free of fear, trauma and anxiety and helping the child to express views freely.
- Continuous and Comprehensive Evaluation of child understanding and knowledge and his / her ability to apply the same.

Section 30 (1): No child shall be required to pass any Board examination till completion of elementary education.

(2) Every child completing his elementary education shall be awarded a certificate, in such form and in such manner as may be prescribed.

1. The Nature of Science

The Nature of Science – Scope – The Nature of Knowledge

Over the course of human history, people have developed many interconnected and validated ideas about the physical, biological, psychological, and social worlds. Those ideas have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environment. The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways represent a fundamental aspect of the nature of science and reflect how science tends to differ from other modes of knowing. Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study.

Science also assumes that the universe is, a vast single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to other parts. For instance, the same principles of motion and gravitation that explain the motion of falling objects on the surface of the earth also explain the motion of the moon and the planets.

Scientific Knowledge is Subject to Change

Science is a process of constructing knowledge. The process depends both on making careful observations of phenomena and on inventing theories for making sense out of those observations. Change in knowledge is inevitable because new observations may challenge prevailing theories.

Scientific Knowledge is Long-lasting

This appears to contradict what was told earlier. But the important fact here is, most scientific knowledge is durable. For example, in formulating the theory of relativity, Albert Einstein did not discard the Newtonian laws of motion but rather showed them to be only an approximation of limited application within a more general concept. Continuity and stability are as characteristic of science as change is, and certainty as prevalent as tentativeness. Hence, there will as many (or even more) uncertain things as things that we are certain of.

Science Cannot Provide Complete Answers to All Questions

There are many matters that cannot usefully be examined in a scientific way. There are, for instance, beliefs that-by their very nature-cannot be proved or disproved (such as the existence of supernatural powers and beings, or the true purposes of life).

Scientific Inquiry

Plato believed that only through the mind we can arrive at reason and truth. Science asks three basic questions. They are:

What is there? (E.g. What is in this stone? What is there in the Moon?)

How does it work? (E.g. How does air help plants to prepare their food?)
How did it come to be this way? (looking at a fossil or a stone).

This is scientific inquiry. Fundamentally, the various scientific disciplines are alike in their reliance on evidence, the use of hypothesis and theories, the kinds of logic used, and much more. Scientific inquiry is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge. There are, however, certain features of science that give it a distinctive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in everyday life.

Science Demands Evidence

When a phenomenon is taken for scientific inquiry, theoretical proof of 'how it happens' or 'what is the truth' is not just enough. It needs tangible evidence. The validity of scientific claims is settled by referring to observations of phenomena. Hence, science concentrates on getting accurate data.

Science Is a Blend of Logic and Imagination

Scientific concepts do not emerge automatically from data or from any amount of analysis alone. The assumption has to be connected with conclusions through scientific arguments that conform to the principles of logical reasoning. Sometimes discoveries in science are made unexpectedly even by accident and often by leaps of imagination.

Science Explains and Predicts

The predictions may be about evidence from the past that has not yet been found or studied. A theory about the origins of human beings, for example, can be tested by new discoveries of human-like fossil remains. This approach is clearly necessary for reconstructing the events in the history of the earth or of the life forms on it. It is also necessary for the study of processes that usually occur very slowly, such as the building of mountains or the aging of stars.

Science Is a Complex Social Activity

Scientific work involves many individuals doing many different kinds of work and goes on to some degree in all nations of the world. Men and women of all ethnic and national backgrounds participate in science and its applications. These people—scientists and engineers, mathematicians, physicians, technicians, computer programmers, librarians, and others—may focus on scientific knowledge either for its own sake or for a particular practical purpose, and they may be concerned with data gathering, theory building, instrument building, or communicating.

2. How do Children Learn Science?

The essential feature of science is the spirit of enquiry and discovery and so it becomes the basis for science teaching. An understanding of science requires a definite to minimum of basic factual knowledge and vocabulary and some real experience of investigation coupled with a knowledge and understanding of the ways in which scientific methods are used. Science teaching must engage the children who are curious and question everything. It is understood from the nature of science that it is not just a body of knowledge but a process to develop knowledge. Therefore, science teaching must not be didactic. Often it is the scientist's discovery/invention that is highlighted in content and never the background how he/she arrived at that discovery/invention. The process how they arrived at it is crucial to develop conceptual understanding, inculcate the scientific method of enquiry so this process is to be highlighted/emphasized in the teaching process.

Science is a systematic, careful and continuous inquiry/investigation through, experimentation for verification on validation. Hence, the activities and experiments in the classroom must be designed to nurture and channel curiosity, ask questions, make observations and lead to an open argumentation that leads to evolve the acceptable, accurate solution/conclusion in a democratic way. It is vital that children are prepared through science teaching to construct knowledge and engaged in continuous enquiry to satisfy their innate curiosity. Science and technology is ever expanding/progressing by constant experimentation and verification on validation developing new theories, inventions or sometimes come up with improved version that explains more phenomena thus the quality of flexible attitude is to be fostered to be tolerant to accept others view or to critically appraise and assess it. Scientific concepts knowledge do not emerge automatically they are labour of love of some scientists or group of scientist's commitment to know the unknown. What science accepts as knowledge and recognize as knowledge is after validation, verification though experimentation. The children are to be encouraged to conduct their projects in a systematic and analytical way.

How do Children Learn Science?

Let us see an instance of how children learn science. One day, Ravi and Ramu wanted to fly a kite. They made a kite pasting a few sticks to a piece of paper taken from old newspapers. The tied some thread, went upstairs, observed the direction of the wind, and tried to fly it. But it did not fly. They measured and checked if the knot is alright before they tried it for the second time. Even then, the kite did not fly. They thought that the tail is too short, so they pasted some more pieces of paper to make it longer. This time the kite went up and up but then it came tumbling down. Now they had a clue. They shortened it a bit and then successfully flew the kite.

Observe the above incident carefully. How did the children learn the science behind 'how does a piece of paper transform into a kite and fly in the air?' You wonder whether children will be able to answer questions like: What happens if there is a change in the length or width or both? Why should the sticks be pasted in a certain way? What happens if the point where the thread is knotted changes? Is there a relation between the size of the kite and its tail? Why does not the kite fly in the direction opposite to the wind direction? What kind of thread should be used to fly a kite? Whey does not the kite fly if it is flown from ground instead of the top floor. We also have a doubt whether children will ever think of such things. When children try to fly a kite, they move forward by learning through trial and error and discussing with logical reasoning.

When the kite does not fly, they investigate the problem and come out with some assumptions (hypotheses) and consequently with some 'things to do' to solve the problem. Then they apply them, validate their assumptions and ultimately solve the problem. This is what we mean by thinking scientifically. We call it the Scientific Method. This is the underlying principle of science.

Children by nature have very close relations with their surroundings. They analyze their experiences with the surroundings from their own angle. At upper primary stage meticulous observation, creative solutions to problems and logical reasoning start blossoming in the child, so the objective of school should be to channelize these competencies properly and guide them to learn science.

Everything in the world around us is bound by some principles and laws. Identifying them is the prime objective of science. To know this, questions like Why? What? How? Etc., must be asked. Science is in every work like riding a bicycle, playing cricket, throwing stones to fell fruits, and cooking. Children understand the principles and laws hidden in them in their own way. They generalize in their own style. This demonstrates the need to give a lot of importance to 'learning by doing' in the teaching learning activities developed to teach science. Children learn everything by keen observation and trial and error method. Pedagogically, we call them process skills. Children never do a thing presuming that there is an underlying principle in the work they do which is called science. This means, they give importance to process rather than the product. Learning science depends a lot on this key factor. A scientist does not work to find solutions to a specified problem. New inventions/discoveries are made or new problems arise as s/he goes on exploring. This is done naturally and creatively without any pressure or obligation.