



**Q & A**  
**SCIENCE AND MATHEMATICS**  
**IN**  
**NCF-2005**

**UPPER PRIMARY, SECONDARY AND  
HIGHER SECONDARY STAGES**

**DEPARTMENT OF EDUCATION IN SCIENCE AND MATHEMATICS**  
**National Council of Educational Research and Training**

# Q & A

**SCIENCE AND MATHEMATICS**

IN

**NCF-2005**

**UPPER PRIMARY, SECONDARY AND  
HIGHER SECONDARY STAGES**

*Key Issues and Concerns of NCF-2005 for  
Science and Mathematics Re-emphasised for  
their Easy Implementation*

**Department of Education in Science and Mathematics**



**राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्  
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## FOREWORD

The National Curriculum Framework (NCF, 2005) presents a fresh perspective on the teaching of different school subjects, including the natural sciences and mathematics. This perspective has been derived from contemporary theoretical understanding of children's cognitive development on one hand, and serious engagement with the epistemological issues pertaining to each major school subject, on the other. In the context of teaching, the insights and recommendations provided in NCF have been further elaborated in the position papers of the National Focus Groups on Science and Mathematics chaired respectively, by Professor Arvind Kumar, former Director, Homi Bhabha Centre for Science Education, Mumbai, and Professor R. Ramanujam, Centre for Ecological Sciences, Institute of Mathematical Science, Chennai. The insights and recommendations of these documents have been used to develop the new syllabi and textbooks for all stages in these two key areas of the school curriculum.

The present publication is aimed at providing further commentary and elaboration on the new ideas and concepts that NCF and related documents contain. Our purpose is to familiarise teachers with these ideas and concepts with the help of illustrations drawn from relevant topics. Teachers have a crucial role in translating the recommendations of NCF into pedagogic and assessment strategies which might do justice to the enormous effort that has gone into the making of new syllabus and textbooks of science and mathematics. The idea that classroom knowledge should derive from children's experience and enable them to construct knowledge in successively more complex ways presents a great challenge and opportunity for systemic change.

We hope that this publication will reach teachers and teacher educators all over the country and that it will be utilised in both

in-service and pre-service training programmes. We will expect that it will find readership among senior teachers of science and mathematics as well as principals and other administrative functionaries whose understanding of NCF-related issues can make a crucial input in softening the rigid frames of time, student performance and parental demands which define our system.

I appreciate the contribution made for the successful completion of this document by Professor Arvind Kumar, Professor R. Ramanujam, Dr. Savithri Singh, Mr. Arvind Gupta, Professor Madhav Gadgil, Ms. Harsh Kumari, and Mr. G.B. Pande. I also record my appreciation of the hard work put in by Dr. Shashi Prabha and Professor Hukum Singh, Head, Department of Education in Science and Mathematics. We also acknowledge the contribution made by Curriculum Group, Department of Teacher Education and Extension, Department of Educational Measurement and Evaluation and the Workshop.

New Delhi  
November 2009

*Director*  
National Council of Educational  
Research and Training

## PREFACE

This document is an attempt to convey in brief the main ideas of the NCF-2005 to teachers and all stakeholders of education in Science and Mathematics at the upper primary, secondary and higher secondary stages of school education. After NCF-2005 was brought out, NCERT received very valuable feedback from teachers from different parts of the country through various modes of interaction, particularly during video conferencing programmes. The interaction consisted of queries and comments as well as narration of their experiences during the implementation of NCF-2005. There was also a general feeling of the need for an explanation of the main ideas of NCF-2005 in simple words that would help teachers in deeper understanding of NCF-2005 and its implementation.

Any process of simplification is bound to result in some loss of the richness and subtlety of the original document. This document is therefore not intended to be a substitute for NCF-2005. It is an attempt to explain and re-emphasise some of its ideas and guidelines concerned with science and mathematics. We have adopted an interactive dialogue format for the ease of reading and also to project and clarify queries and doubts that teachers have about NCF-2005. Most importantly, we have tried to avoid a top-down approach where a teacher may raise her doubts and ask questions and someone gives all the wise answers! Instead, the dialogue is designed on equal terms respecting teachers' queries and narration, even as NCF-2005 viewpoint is put forth. The answers are intended to indicate the broad consensus of all stakeholders in the system—including those who were involved in the development of NCF-2005.



The book contains five parts, i.e., three chapters and two annexures. Chapter 1 explains about major concerns and perspectives of NCF-2005. Criteria for an ideal science curriculum, the main goal of mathematics education and the shift in focus from mathematical content to mathematical learning environment where a whole range of processes take place are discussed in Chapter 2. If children's classroom experiences are to be organised in a manner that permits them to construct knowledge, then our teachers need to feel empowered for it. Chapter 3 includes a dialogue with the teachers about their apprehensions and difficulties faced by them in implementing the essence of NCF-2005, and issues related to the examination reforms. Annexure-I gives a glossary of key terms and phrases appearing in NCF-2005 for ready reference. Annexure-II gives some examples and anecdotes that the teachers should be able to readily relate to. Most of the examples have been carried out by practising teachers in the classrooms. The development team met a few times to revise, refine and edit this document.

We hope this document will serve its purpose to explain the main ideas of NCF-2005 and help in its implementation. Teacher educators, policy makers and other field functionaries will find it equally useful.

ARVIND KUMAR  
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*In a progressive forward-looking society, science can play a truly liberating role, helping people out of the vicious circle of poverty, ignorance and superstition. In a democratic political framework, the possible aberrations and misuse of science can be checked by the people themselves. Science, tempered with wisdom, is the surest and the only way to human welfare. This conviction provides the basic rationale for science education*

POSITION PAPER ON TEACHING OF SCIENCE (p. 2)

## About the National Curriculum Framework-2005

A discussion on what NCF-2005 is and what it aims for

### **Q.1 What does the *National Curriculum Framework-2005* deal with?**

- A.1 Certain broad aims of education have been identified in the *National Curriculum Framework-2005* (NCF-2005) seeking guidance from the constitutional vision of India as a secular, egalitarian and pluralistic society. These include independence of thought and action, sensitivity to others' well-being and feelings, learning to respond to new situations in a flexible and creative manner, predisposition towards participation in democratic processes, and the ability to work towards and contribute to economic processes and social change.

NCF-2005 provides a guideline with which teachers and schools can choose and plan experiences that they think children should have. It is a reviewed version of NCF-2000 in the light of the report *Learning Without Burden* (1993, Professor Yashpal). To make teaching a means of harnessing the child's creative nature, the report recommended a fundamental change in the matter of organising curriculum and also in the system of examination which forces children to memorise information to reproduce it. The *National Curriculum Framework* emphasises that curriculum, syllabus and text books should enable the teacher to organise classroom experiences in consonance with the child's

nature and environment, and provide opportunities to all children. Significant changes are recommended with a view to the present day and future needs in order to alleviate the stress, children are coping with today. NCF-2005 sets out the broad conceptual framework and guidelines regarding school education in India from early childhood stage to the higher secondary stage of education in its five chapters (i) Perspective (ii) Learning and Knowledge (iii) Curriculum Areas, School Stages and Assessment (iv) School and Classroom Environment (v) Systemic Reforms.

**Q.2 In what way is a 'curriculum framework' different from a 'curriculum'?**

A.2 A 'curriculum framework', as the word suggests is a broad framework of concepts and guidelines that informs the school education policy of a country. It is a plan that interprets educational aims vis-a-vis both individual and society to arrive at an understanding of the kind of learning experiences teachers should provide to children. Its scope is wide and it relates all those who are concerned with education—students, teachers, parents, teacher educators, policy makers and the public at large.

A 'curriculum' is guided by the 'curriculum framework'; it pertains to learning experiences in and outside the classroom, and the enabling conditions needed for the desired teaching-learning process. It includes content, pedagogy, systemic characteristics and assessment.

**Q.3 Is 'syllabus' the same thing as 'curriculum'?**

A.3 'Syllabus' refers to the content of each subject in the curriculum. It outlines what is to be taught and the knowledge, skills and attitudes which are to be deliberately fostered, together with stage-specific objectives. Syllabus also contains time allotment and assessment scheme for each subject. Moreover, the current syllabus developed by the NCERT provides guidelines to teachers to connect school knowledge with child's experiences.



**Q.4 What is the need for bringing out a new 'curriculum framework' document? Do we not already have an education policy underlying school education in India?**

- A.4 India's National Policy on Education (NPE), 1986 proposed a national framework for curriculum as a means of evolving a national system of education. This system is aimed to be capable of responding to India's diversity of geographical and cultural milieus while ensuring a common core of values along with academic components. The policy has also entrusted NCERT with the responsibility of developing and promoting the National Curriculum Framework and reviewing the Framework at frequent intervals.

The National System of Education will be based on a national curricular framework, which contains a common core along with other components that are flexible. The common core will include the history of India's freedom movement, the constitutional obligations and other contents essential to nurture national identity. These elements will cut across subject areas and will be designed to promote values such as India's common cultural heritage, egalitarianism, democracy and secularism, equality of sexes, protection of environment, removal of social barriers, observance of small family norm and inculcation of scientific temper. All educational programmes will be carried on in a strict conformity with secular values. India has always worked for peace and understanding between nations, treating the whole world as one family. True to this hoary tradition, education has to strengthen this world-view and motivate the younger generations for international cooperation and peaceful co-existence. This aspect cannot be neglected. To promote equality, it will be necessary to provide equal opportunity for all, not only in access but also in the condition of success. Besides, awareness of the inherent equality of all will be created through the core curriculum. The purpose is to remove prejudices and complexes transmitted through the social environment and the accident of birth.

*NATIONAL POLICY ON EDUCATION, 1986*

Hence, NCERT has formulated NCFs in 1975, 1988, 2000 and recently in 2005. Further, you would agree without any doubt that a curriculum framework for any society cannot be a static document, 'frozen' in time. With the creation of new knowledge all over the world, socio-cultural and economic conditions of our society change, new opportunities of work arise and aspiration of people grow. This dynamism of the society must be reflected in school education.

**Q.5 I appreciate it. I suppose the new knowledge that you referred to now also includes new ideas and insights on education itself, that is, our steadily evolving views on teaching-learning process, educational technology, and so on.**

A.5 You are absolutely right. The paradigm (i.e., the conceptual foundations and broad principles) of school education itself is being debated and clarified all over the world. Further, experiences of NCERT and other educational agencies as well as the field work of several NGOs throw new insights into and ideas on education in India. NCF-2005 encapsulates the emerging insights into education in India.

NCF-2005 says that we need to pay attention to new developments and concerns to which our Universal Elementary Education (UEE) emphasises. There is a need to broaden the scope of the curriculum to include the rich inheritance of different traditions of knowledge, work and crafts. Some of these traditions today face a serious threat from market forces and the commodification of knowledge in the context of globalisation of the economy. The development of self-esteem and ethics, and the need to cultivate children's creativity, must receive primacy. In the context of a fast-changing world and a competitive global context, it is imperative that we respect children's native wisdom and imagination.

**Q.6 Could you throw some light on the major concerns addressed in NCF-2005?**

A.6 One major concern is that our school system has, over the years, become rigid and inflexible. In the process, our education tends to suppress the natural creativity and curiosity of children. One of the reasons why this has happened is the dominating role of examinations in our system. The examination that supposedly determines child's future occupies the centre stage and child's presence has gone to the background. What is necessary is to give primacy to children's experiences and their voices and to encourage their active participation in learning. NCF-2005 points out that every child is talented in some way. We need to identify and nurture talent of each child.

Another major concern is that quality school education has still not reached to a large section of our population. There is no doubt about some 'islands' of excellence, but the large majority of marginalised groups such as girls, socio-economically disadvantaged children, etc., do not get meaningful learning experiences in school, which will give them a sense of dignity and confidence. Curriculum design must reflect the commitment to Universal Elementary Education (UEE), not only in representing cultural diversity, but also by ensuring that children from different social and economic backgrounds with variations in physical, psychological and intellectual characteristics are able to learn and achieve success in school. In this context, disadvantages in education arising from inequalities of gender, caste, language, culture or religion need to be addressed directly, not only through policies and schemes but also through the design and selection of learning tasks and pedagogic practices, right from the period of early childhood. Education must empower them to overcome the disadvantages of unequal socialisation and enable them to develop their capabilities of becoming autonomous and equal citizens. The *National Curriculum Framework-2005* is focused on providing quality education to all children.

**Q.7 Now I understand that there are major concerns and problems in the educational scenario of our country. Does NCF-2005 address these concerns?**

A.7 I am glad you asked this question. Indeed, NCF-2005 was formulated mainly in response to the widespread concerns of teachers and other stakeholders throughout the country. Addressing these concerns NCF-2005 suggests that school knowledge needs to be connected with day-to-day experiences of the child. It also recommends plurality of text books, continuous and comprehensive evaluation, flexibility in examination and time schedules of school and also mother tongue as the medium of instruction.

**Q.8 I appreciate these recommendations. Also, I agree with you on quality of education that you explained. Indeed all responsible citizens of our country must be concerned about these two issues: (i) the need to universalise school education making it accessible to all marginalised groups and (ii) the need to enhance its quality. But, we have been discussing and debating these matters for years. What is new in NCF-2005 regarding these long-standing problems?**

A.8 The issues are deep and the problems are gigantic. There is no magical solution being offered by NCF-2005. But it has projected and focused on these issues with greater clarity and given several practical measures to make progress with regard to them.

NCF-2005 has two very significant things to say about the twin major concerns expressed above. First, universalisation of education and quality in education are not to be regarded as two 'opposing' needs. They are complementary and reinforce each other. Quality cannot flourish for long in a society that is not based on equality and justice for all. Likewise, universalisation can be an empty slogan unless quality is assured for all. Second, NCF-2005 interprets the quality dimension holistically, departing from its narrow connotation of excellence in particular subject areas.

**Q.9 I wholly agree with what you said about universalisation. Quality and universalisation are no doubt inseparable. But I did not get exactly what you have in mind regarding the broad meaning of 'quality education'.**

A.9 Before I come to that let me understand your own views on 'quality', since it is the teacher who plays a pivotal role in ensuring quality education for all.

**Q.10 In my view, quality education means children should be involved in joyful and meaningful learning at schools that leads them to attain the necessary life skills and become good and useful members of the society. Am I right?**

A.10 Yes, exactly. NCF-2005 says much the same thing. It emphasises that school learning should not be confined to textbooks alone; teaching-learning experiences should be embedded in the child's life experiences. For this, it is necessary that learning should be shifted from rote method. This clearly requires that the school system should be flexible, allowing innovation and promoting creativity among children. Overall development of the child should be emphasised. Thus quality in education includes concern for quality of life in all its dimensions. This is why a concern for peace, protection of the environment and predisposition towards social change must be viewed as core components of quality, not only as value premises.

**Q.11 You mentioned that NCF-2005 interprets 'quality' very broadly. What other aspects does 'quality' refer to?**

A.11 We have already agreed that 'quality' is inclusive of universalisation. The document clearly explains that quality is a systemic characteristic rather than only a feature of instruction or attainment. The attempt to improve the quality of education will succeed only if it goes hand in hand with steps to promote equality and social justice.

Equality in education can be brought by enabling all learners to claim their rights as well as to contribute to society and the polity. Quality education should promote

these social values necessary for a democratic society such as ours.

**Q.12 In continuation of the same discussion, there has been much talk of the so-called 'constructivism' in NCF-2005. What does this term mean?**

A.12 'Constructivism' is not a new mysterious educational philosophy— it has always been a part of the good pedagogical practices. NCF-2005 clarifies and projects it with emphasis, mainly to promote quality education that we discussed above. Constructivism holds that knowledge should not be regarded as 'out there' to be emptied into the child's head. Rather, it recognises that meaningful learning involves the child 'constructing' knowledge by himself/herself. This happens by actively engaging the learner. School must provide every possible opportunity to children for this. Active engagement involves inquiry, exploration, questioning, debates, application and reflection, leading to meaningful understanding, arriving at concept and creation of new ideas.

This term can further be explained by reproducing a part of the text from NCF-2005 (p. 17) as given below:  
*"In the constructivist perspective, learning is a process of the construction of knowledge. Learners actively construct their own knowledge by connecting new ideas to existing ideas on the basis of materials/activities presented to them (experience). For example, using a text or a set of pictures/visuals on a transport system coupled with discussions will allow young learners to be facilitated to construct the idea of a transport system. Initial construction (mental representation) may be based on the idea of the road transport system, and a child from a rural setting may form the idea centred around the bullock cart. Learners construct mental representations (images) of external reality (transport system) through a given set of activities (experiences). The structuring and restructuring of ideas are essential features as the learners progress in learning. For instance, the initial idea of a transport system built around road transport will be reconstructed to*

*accommodate other types of transport systems—sea and air—using appropriate activities. The engagement of learners, through relevant activities can further facilitate in the construction of mental images of the relationship (cause-effect) between a transport system and human life/economy. However, there is a social aspect in the construction process in the sense that knowledge needed for a complex task can reside in a group situation. In this context, collaborative learning provides room for negotiation of meaning, sharing of multiple views and changing the internal representation of the external reality.”*

**Q.13 If the child is to ‘construct’ knowledge himself/herself what then is the role of the teacher? Is the teacher redundant in the process?**

A.13 Not at all. The teacher plays a crucial role, by creating enabling and supporting conditions for the process of ‘Knowledge Construction’ by the child to happen. In this context, teacher is a facilitator who encourages learner to reflect, analyse and interpret in the process of construction of knowledge. Teacher creates various situations wherein students interact with the teacher and understand the concepts, and then the teacher refines or revises those concepts by asking questions, posing contradictions and engaging them in inquiries. Teacher engages her students in discussion in a democratic set-up of the classroom to facilitate them to understand the words and concepts not understood yet. She makes the children aware that their experiences and perceptions are important. They are encouraged to develop the mental skill needed to think and reason independently and to have the courage to dissent. Thus the role of the teacher in the construction of knowledge of her students is to provide a safe space to express themselves without fear of being ridiculed and simultaneously to build certain forms of interaction.



**Q.14 In particular, what are the facilitating conditions for the children's knowledge construction?**

A.14 Teacher should provide an environment conducive to learning, where children feel secure, where there is absence of fear and which is governed by relationships of equality and equity. If students feel that they are valued and their own knowledge about their surroundings such as their homes, communities, languages and cultures are valuable as resources of experiences to be analysed and inquired into at school, they get motivated to learn. The curriculum must enable children to find their voices, nurture their curiosity, to do things, to ask questions and to pursue investigations, sharing and integrating their experiences with school knowledge. Learning should not be equated with children's ability to reproduce textual knowledge.

**Q.15 Would you please give some ideas for integrating children's experiences and local knowledge with their learning?**

A.15 Sure, it is students' interaction with their environment and integration of their experiences and local knowledge, that leads to meaningful learning. NCF-2005 emphasises the significance of contextualising education, of situating learning in the context of the child's world, and of making the boundary between the school and its natural and social environment porous. This is not only because the local environment and the child's own experiences are the best entry points into the study of different disciplines of knowledge, but more so because the aim of knowledge is to connect with the world. It is not a means to an end, but both means and end. This does not require us to reduce knowledge to the functional and immediately relevant, but to realise its dynamisms by connecting with the world through it. The local environment is thus a natural learning resource, which must be privileged when making choices regarding what should be included in the curriculum or what concrete examples should be cited in planning for their transactions in the classroom.

## LOCAL KNOWLEDGE TRADITIONS

Many communities and individuals in India are a rich storehouse of knowledge about many aspects of India's environment, acquired over generations and handed down as traditional knowledge, as well as through an individual's practical experiences. Such knowledge may pertain to: naming and categorising plants, or ways of harvesting and storing water, or of practising sustainable agriculture. Sometimes these may be different from the ways in which school knowledge approaches the subject. At other times, it may not be recognised as something that is important. In these situations, teachers could help children develop projects of study based on local traditions and people's practical ecological knowledge; this may also involve comparing these with the school approach. In some cases, as in the case of classifying plants, the two traditions may be simply parallel and be based on different criteria considered significant. In other cases, for example the classification and diagnosis of illnesses, it may also challenge and contradict local belief systems. However, all forms of local knowledge must be mediated through Constitutional values and principles.

*NCF-2005 (p. 32)*

### **Q.16 I recognise that knowledge is different from information. What does NCF-2005 say about it?**

A.16 Knowledge can be conceived as experiences organised through language into patterns of thought, thus creating meaning, which in turn helps us to understand the world we live in. It is important that all children learn to participate in the very process of knowledge creation, as this constitutes the basis for further thinking and for acting appropriately in the world. Conceiving knowledge in this broad sense directs us to the significance of dynamic engagement of the children with the world through observing, inquiring, experimenting, discussing, listening,

thinking and reflecting—both individually and with others. Here you engage the children actively. If, on the other hand, knowledge is regarded as a finished product, then it is organised in the form of information to be ‘transferred’ to the children’s mind. In this view of knowledge, children are conceived as passive receivers of knowledge.

**Q.17 Let us return to the all-important question of universalisation. What are the recommendations of NCF-2005 in this regard?**

A.17 We have already discussed about it (please refer Q. 6). Broadly speaking, the recommendations of NCF-2005 regarding universalisation are: (i) inclusion and retention

The formal approach, of *equality of treatment*, in terms of equal access or equal representation for girls, is inadequate. Today, there is a need to adopt a substantive approach, towards *equality of outcome*, where diversity, difference and disadvantage are taken into account.

A critical function of education for equality is to enable all learners to claim their rights as well as to contribute to society and the policy. We need to recognise that *rights and choices in themselves cannot be exercised until central human capabilities are fulfilled*. Thus, in order to make it possible for marginalised learners, and especially girls, to claim their rights as well as play an active role in shaping collective life, education must empower them to overcome the disadvantages of unequal socialisation *and enable them to develop their capabilities of becoming autonomous and equal citizens*.

NCF-2005 (p. 6)

of all children in school through proper design of learning tasks that reaffirms the value of each child and enables all children to experience dignity and confidence to learn; (ii) to ensure quality and equality of outcome for children from different social and economic backgrounds; and (iii) inclusion of the rich inheritance of different traditions of knowledge, work and craft.

**Q.18 Universalisation is, of course, a Constitutional requirement. We must give equal treatment to all, irrespective of caste, class, clan, religion, language, region, etc. What is new in NCF-2005?**

A.18 NCF-2005 goes beyond equality of treatment. It emphasises that school education should be so geared that there is equality of outcome. *Equality of treatment* focuses only on parity across different groups, for example, equal representation of all in the curriculum and textbooks.

*Equality of outcome* emphasises that the processes of education have to be designed to ensure that the marginalised groups are able to relate to the curriculum and teaching practices with their experiences and native wisdom so that they can overcome disadvantages and be able to perform on par with everyone.

**Q. 19 I agree that these ideas are good. But they seem rather idealistic and not practical. How will a teacher like me implement these various recommendations in practice?**

A.19 A majority of teachers have a similar feeling. This is because our education system is textbook and examination centric. We need to go beyond the textbooks and see connectivity between child's everyday life experience and the knowledge school provides. Once we develop faith in child's abilities, we will be able to design challenging tasks for her learning and move towards engaging her in observation, enquiry and construction of knowledge. The ideas we have discussed above may seem impractical in the beginning but that is because we are not used to them. Experience shows that once teachers start implementing these ideas they begin to feel comfortable with them and indeed enjoy interacting with children with this new approach. Teacher autonomy is essential for ensuring learning environment that addresses children's diverse needs. It is important to appreciate that as much as the class room needs to nurture a democratic, flexible and accepting culture, so also the school institution and the bureaucratic structure need to do the same.

### **Science and Mathematics Learning**

Key issues and ideas of NCF-2005 pertaining to science and mathematics; doubts resolved

**Q.1 NCF-2005 states that ‘good science education is true to the child, true to life and true to science’. What is this supposed to mean?**

A.1 In the context of NCF- 2005 ‘true to child’ means that the science we teach should be understandable to the child and be able to engage the child in meaningful and joyful learning.

‘True to life’ means that the science we teach should relate to the environment of the child, prepare her for the world of work and promote in her concerns for life and preservation of the environment.

‘True to science’ means the science we teach should convey significant aspects of science content at appropriate level and engage the child in learning the processes of acquiring and validating scientific knowledge.

**Q.2 NCF-2005 refers to six ‘validities’ of a good science curriculum. What does that mean?**

A.2 This is just a way of saying what the essential features of a good science curriculum are. The six different validities refer to cognitive, content, process, historical, environmental and ethical aspects of a science curriculum. They should provide base for the teaching learning of science. These validities do not set the limit for the teachers. On the

contrary, they provide freedom to the teacher to plan a variety of experiences to seek participation of her students in learning process.

### **Q.3 Should I understand these in more concrete terms?**

A.3 Yes indeed. Let us see few examples that satisfy the required validity and alongwith them the counter examples that illustrate the topics not reflecting the required validity.

#### **Cognitive validity**

Cognitive validity implies that the content should be age appropriate so that children can understand them. The way of transaction of the content should be according to the level of the child.

Example:

Up to upper primary level, the basic concepts of light are transacted qualitatively taking concrete examples from their surroundings. At the secondary stage, the ability of logical thinking and abstract reasoning develops. Therefore, children are introduced to draw ray diagrams explaining formation of images using different types of lenses and mirrors. At higher secondary stage, children are ready to understand the broader concepts of light like principle of various optical instruments using relevant formulae and solving problems with appropriate rigour. '*Wave Theory of Light*' at higher secondary stage satisfies cognitive validity. Based on this reasoning we decide which topic should be taken up at which stage.

Teaching '*Formation of Shadows*' in class VI, and '*Differential Calculus*' in class XII also satisfy cognitive validity.

Counter example:

Teaching '*Wave Theory of Light*' in class VII or '*Irrational Numbers*' in class VI do not satisfy cognitive validity.

#### **Content validity**

It requires that curriculum must convey significant and scientifically correct content. We should not teach grossly incorrect science in our effort to simplify it. The idea that

electron pairs are equally shared in all covalent bonds should be reconstructed as electron pairs are not shared equally in all covalent bonds. In some, one atom attracts the electron pair more than the other atom (i.e., a difference in electronegativity) and causes the electron pair to be closer to it than to the other atom.

Example:

The spontaneous and widespread idea of students at secondary stage that force is directly proportional to velocity should be carefully transformed into the correct idea that force is directly proportional to acceleration. This is necessary for satisfying content validity.

Counter example:

Explaining '*Darwinian Theory of Natural Selection*' as a 'natural desire' of species to survive; matter is destroyed during burning; electric current is used up in lighting the bulb; do not fulfil the requirement of content validity.

### **Process validity**

It is an important criterion of a good science curriculum. It helps children in learning to learn science. It implies that we should not focus only on the content but also ensure that while teaching, the right pedagogic processes are used that enable interactive and activity-based learning. Curriculum should engage the learners in acquiring the methods and processes of learning science so that they can generate and validate the scientific knowledge. It should develop a spirit of enquiry, objectivity, creativity and open-mindedness among the learners. In order to satisfy the process validity, children should be given all possible opportunities of observation, classification, measurement, making hypothesis, experimenting, reasoning, arriving at conclusions and communicating results in teaching-learning situations of science.

Example:

Learning '*Faraday's Law of Electromagnetic Induction*' through a variety of different situations in the laboratory: magnet and coil in relative motion, two current carrying coils in the vicinity of each other, etc. and arriving at the



mathematical law followed by solving problems and critical conceptual questions, satisfy process validity. Similarly, arriving at the approximate value of  $\pi$  as nearly 3.14 by the students after finding the ratio of circumference to the diameter of different circles and then generalising it themselves meets the requirement of process validity.

Counter example:

Verbal description of the arrangement of flowers (inflorescence) in a plant, without exposure to plants in the environment does not fulfil the requirement of process validity. Other counter examples are teaching '*Laws of Reflection and Refraction of Light*' or '*Magnet*' without providing the children situations of performing activities and experiments.

### **Historical validity**

It means that science teaching should not convey a static image of science. It should be informed by historical perspective enabling the learner to appreciate how the concepts of science evolve with time with better and more reliable theories. Satisfying historical validity helps the learner to view science as a social enterprise and to understand how social facts influence the development of science.

Example:

The '*Periodic Table*' in Chemistry was earlier based on atomic weight, later based on atomic number, and finally explained by quantum theory. The concept of '*genes*' in terms of its phenotypic expression or molecular understanding of '*gene*' with reference to structure of DNA accomplish the requirement of historical validity.

Counter example:

Teaching '*Heliocentric Theory of Solar System*' without any reference to the earlier '*Geocentric*' model; teaching '*Wave Optics*' without reference to the historical debate between the wave and corpuscular pictures of light do not meet the requirement of historical validity.

## 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 tuar 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, medicines, fuelwood, dyes and building materials; she has observed parts of different plants used for household purposes, in religious rituals and in celebrating festivals. She recognizes 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 Janbai 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: 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 Janabai truly learn science.

*POSITION PAPER ON TEACHING OF SCIENCE (p.14)*

### **Environmental validity**

It means that science teaching should be contextualised and related with the child's environment. Curriculum of science should enable the learner to appreciate the issues at the interface of science, technology and society. It should also equip them with the requisite knowledge and skills to enter the world of work.

Example:

Encouraging children to build models of windmill, solar cooker; relating global warming with carbon dioxide emission from burning of wood and increasing number of automobiles; relating neutralisation of acid with base with ways of treatment of soil to decrease alkalinity or acidity are some examples satisfying environmental validities.

Counter example:

Teaching biodiversity in a school in tribal areas without any field visit to the surrounding area; teaching concepts of sound without any sensitisation to noise pollution does not satisfy environmental validity.

### **Ethical validity**

It means science education should promote values of honesty, objectivity, cooperation, freedom from fear and prejudices, and concerns for life and the environment.

Example:

Encouraging children to report the experimental and observational data honestly and critically, enquiring into the reasons for departure from standard or expected value, if any, establishes ethical validity.

Counter example:

Being insensitive to water and electricity wastages in schools and homes, indulging in cutting of trees and cruelty to animals does not satisfy ethical validity.

### **Q.4 Knowing NCF-2005 perspective on science, now I am curious to know what are the thrusts of NCF-2005 with respect to mathematics education?**

A.4 As per NCF-2005, the main goal of mathematics education is the development of children's ability of mathematisation.

### **Q.5 What does that mean?**

A.5 Basically it means that children should learn to think about any situation using the language of mathematics so that the tools and techniques of mathematics can be used. This typically involves— drawing pictures (representations), choosing variables, framing equations and arriving at a conclusion logically.

**Q.6 Would you please explain it with the help of an example?**

A.6 Sure. Let us consider, length of a rectangular field is two times its width and its area is 400 square metres. This situation can be expressed (mathematised) as  $(2x)(x)=400$  choosing  $x$  as a variable representing width of the field.

**Q.7 But you talk of narrow and higher aims of mathematics. Why does one make such a distinction?**

A.7 The difference is basically between numeracy-related skills such as the ability to deal with arithmetic operations, ability to compute percentage, area, volume, to factor polynomials etc., and the mathematics required to handle abstraction. The former is needed to transact one's daily life business along with social obligations smoothly. It is of immediate need. But the later is important to deal with the modern complex technological world.

**Q.8 How do you visualise achieving the higher aim of mathematics in our education?**

A.8 It is possible by developing the child's capability for logical and analytical thinking, nurturing a confident attitude to problem solving, and an ability to decide which mathematical tools are appropriate in which context and to apply them accordingly.

**Q.9 NCF-2005 talks about teaching ambitious, coherent and important mathematics. What does that mean?**

A.9 An ambitious mathematics seeks to achieve the higher aim rather than only the narrower aim. Coherent means linkages of mathematics with other subjects. Teaching important mathematics means that it is not merely textbook material but something both children and teachers consider worth spending their time and energy on, and mathematicians consider significant for mathematics. An important consequence of such requirements is that school mathematics must be activity oriented.

**Q.10 It is appreciable. Could you next explain the meaning of nature of mathematics?**

A.10 Mathematics reveals hidden patterns that helps us to understand the world around us. Much more than arithmetic and geometry, Mathematics today is a diversified discipline, which deals with data, measurement and observations from science; with reference, deduction and proof, and with mathematical models, natural phenomena, human behaviour and social systems. As a practical matter, mathematics is a science of patterns and order. Its domain is not molecules or cells, but numbers, chance, form, algorithm and change. As a science of abstract object, mathematics relies on logic rather than on observation as its standard of truth, yet employs observation, simulations and even experimentation as means of discovering the truth. The result of mathematics—theorems and theories—are both significant and useful; the best results are also elegant and deep. In addition to theorems and theories, mathematics offers distinctive mode of thought which are both versatile and powerful, including mathematical modelling, abstraction, optimisation, logical analysis, inference from data and use of symbols. Due to diverse application of mathematics, the various mathematical tools are required which are interlinked with each other. It is the tall shape of mathematics.

**Q.11 What is the meaning of ‘the tall shape of mathematics’?**

A.11 Many concepts are needed to be learnt sequentially in mathematics. Only after mastering arithmetic, algebra is learnt, and only when one can factor polynomials, is able to understand trigonometry, and so on. Thus, since each theme is built on another, it results in a tall shape. This makes it difficult for children; someone who finds one stage difficult finds it hard to catch up later.

**Q.12 But, as I understand, that is the nature of mathematics. What does NCF-05 say about it?**

A.12 NCF-2005 says that the tall shape of mathematics can be de-emphasised in favour of a broad-based curriculum

with more topics that start from the basics. Revisiting the basics of mathematics at secondary and higher secondary stages will help children make better use of their time at school.

**Q.13 We often face a difficult choice, especially at the secondary and higher secondary stages, of deciding whether we should teach many topics without much detail, giving children exposure to those topics, or should we cover a few themes in depth, giving children competence. What is the solution to this problem?**

A.13 There are arguments in favour of either choice. It is generally not possible to do both, since there are often conflicting demands of depth versus breadth. There is no general answer to this question. The teacher is the best person to find the right balance, in the given local situation and context.

**Q.14 I appreciate that NCF-2005 advocates this flexibility. I would like to know, whether the meaning of 'constructivism' is the same in the context of mathematics as it is in science?**

A.14 It means the same thing; an approach by which children discover and construct their knowledge, rather than it being simply given and taken uncritically. In mathematics, for example, this means that children's ability to come up with a formula is more important than being able to correctly use well known formulae.

**Q.15 I understand. It means that discovering even simple facts (theorems) on their own, and arguing why they are true is more important than being able to recall famous theorems and their proofs. Am I right?**

A.15 Absolutely. Children view mathematics as something to talk about, to communicate, to discuss among themselves, to work together on. Making mathematics a part of children's life experience is the best mathematics education possible.

**Q.16 I try my best to help children to discover the formulae on their own and I have observed that this way they enjoy mathematics rather than fear it. I understand that mathematics is more than formulae and mechanical procedures.**

A.16 That is great.

**Q.17 What is the meaning of the term 'multiplicity of approaches'?**

A.17 Very often, there are many ways of solving a problem, many procedures for computing a quantity, many ways of proving or presenting an argument. Offering such a choice allows children to work out and use the approach that is most natural and easy for them. For some students who learn more than one approach, this is a technique for self-checking. Multiplicity of approaches is crucial for liberating school mathematics from the tyranny of the one right answer, found by applying the one algorithm taught. When many ways are available, one can compare them, decide which is appropriate when, and in the process gains insight.

For instance, to subtract 53 from 100, you could use the standard algorithm of taking away with borrowing, or consider how people do this in shops. When someone buys material for Rs 53 and gives a hundred-rupee note, the shopkeeper may return as follows: here, four notes of rupees 10, another five rupees and two coins of rupee 1. Here even the answer, 47, is not mentioned but the operation is correct. (This is not an argument to say that children need not learn the standard method, but to say that for children having difficulties, alternatives may help, until they gain confidence.)

**Q.18 What does it mean to shift focus from content to process?**

A.18 In mathematics, content areas are well established: arithmetic, algebra, geometry, trigonometry, mensuration, etc. Our teaching is content oriented, and while it is important to teach content, it is even more important to think of how we teach such content. Here process refers to

pedagogic techniques. For example, many general tactics of problem solving can be taught progressively during the different stages of school. Techniques like abstraction, quantification, analogy, case analysis, reduction to simple situations, even guess-and-verify, are useful in many problem contexts. When children learn a variety of approaches (over a period of time), their tool-kit gets richer and, as we talked about it above, they also learn which approach is best suitable in a given situation. Instead of looking at whether children know something, it is more important to observe how they acquire such knowledge. Though the processes cut across several subject areas, these are central to mathematics. Problem solving, estimation of quantities, approximating solutions, visualisation and representation and mathematical communications are some of the processes of mathematics. As an example, an ability to convert grams into kilograms is important, but more important is the capacity to talk in terms of kilograms for weight of cabbage, and grams for eggs.

**Q.19 What is the meaning of mathematical communication?**

A.19 Precise and unambiguous use of language and rigour in formulation are important characteristics of mathematical treatment. The use of jargon in mathematics is deliberate and stylised. Discussing with appropriate notations aids thinking. That is what mathematical communication means.

**Q.20 I ensure that children give as much importance to setting up the equations as to solving them. Is that also mathematical communication?**

A.20 Yes, you do the right thing.

**Q.21 What is the difference between 'word problem and mathematical modelling'?**

A.21 In word problem, we do not care for physical insight of the problem, but in mathematical modelling, physical insight of the problem is more important. The term modelling is typically used at the secondary stage and later, for



situations where students come up with a mathematical (typically algebraic) formulation to solve them, translating the answers back into the situation. The model is intended to be used later on for other similar purposes. Word problems are similar, but typically used at the elementary stage, and refer to exercises where the child formalises the situation into a form where a specific mathematical technique can be applied. We can think of word problems as 'disposable' (or 'use and throw') models!

**Q.22 Distinguish between use of concrete models, mathematical models and mathematical modelling.**

A.22 When we talk of using concrete models, we are referring to models already built by self or others which make it simpler to comprehend a difficult concept, and to visualise it; for example, cone, cylinder, frustum of cone, etc. used in mathematics laboratory. The meaning of mathematical model is to connect physical situation into mathematics with the help of symbols, such as calculating simple interest

with the help of the formula  $\frac{P \times R \times T}{100}$ , where symbols

have their usual meanings.

Mathematical modelling, on the other hand, is a process of transformation of a physical situation into mathematical analogies with appropriate conditions. It may be an iterative process where we start from a crude model and gradually refine it until it is suitable for solving the problem and enables us to gain insight into and understanding of the original situation. For example, constructing a mathematical model for the estimation of number of fish in a pond without accessing the situation, estimating the number of trees in a dense forest, etc.

**Q.23 What is systematic study of space and shapes?**

A.23 Space is all around us, and we see shapes all the time. But when we see a half-filled glass of water, only systematic study opens our eyes to the circular base, the cylindrical body, an estimate of the volume of water,

etc. Similarly, geometry gives us a sense of symmetry and stability when we look at architecture. Thus, geometry, its systematic understanding using quantities, and its principles (theorems) altogether can be considered the beginning of systematic study of space and shapes.

**Q.24 What is tyranny of procedure?**

A.24 When we learn to do something only as a procedure: “do this, then that, then this”, without understanding why, we not only make mistakes, but also become incapable of applying this learning in a slightly changed situation. A good cook knows not merely the recipe, but also the role-played by each ingredient, so that she can use a different one when something is not available. In mathematics, simply learning formulae without understanding makes for such tyranny, as a consequence, we stop thinking.

**Q.25 What is meaningful problem solving?**

A.25 Exercises at the end of a chapter typically involve only application of a specific skill learnt in a specific situation. Problem solving is more general and should be distinguished. The problem-solving situation is meaningful, when it interests the child who is then motivated to solve the problem, the situation is genuine and the solution is relevant. Meaningfulness is different from interesting stories. A problem asked: Mother made 120 puris, 5 people ate 22 each, how many were left over ? This is utterly meaningless! Even if one can produce a family with 5 people eating exactly the same number of puris, who cares how many are left over after each one ate 22 of them? The only purpose of asking such a question may be to have children reflect on the atrocity of having their mother (or anyone else for that matter) to make 120 puris in the first place!

On the other hand, finding the number of bricks required to make a wall of given dimension is a meaningful problem as it involves the use of concepts of volume as well as concepts of division.

**Q.26 Why is problem posing as important as problem solving?**

A.26 Problem solving usually means a better understanding of the concepts involved, which in turn helps in solving the problem. Problem posing, on the other hand, often requires original and diverse thinking and has many a time resulted in the development of mathematics. For example; (i) Many attempts were made to prove/disprove Euclid's fifth postulate. The work done during these attempts resulted in the development of Non-Euclidean Geometry; (ii) Famous seven bridges problem resulted in the development of a new branch of mathematics called Graph Theory.

**Q.27 What is visual learning in mathematics and why is it important?**

A.27 Learning mathematics by drawing visuals such as number line, bar graph, line graph, histogram, pie chart, etc., is called visual learning. It is important because it facilitates learning, makes it more permanent, and facilitates communication of ideas or result.

### **Towards Implementation**

Obstacles in implementing key ideas, issues and concerns in the context of science and mathematics; softening the boundaries between different subjects and bringing reforms in evaluation: revisiting vision of NCF-2005

**Q.1 NCF-2005 seems to be full of good ideas and intentions. But we are all aware of ground realities of our schools. How are we going to implement these different ideas?**

A.1 Though it has been phrased in general conceptual terms, NCF-2005 is deeply rooted in the ground realities of the country. It was widely debated throughout the country involving different stakeholders of education. Still I appreciate that you are concerned about the obstacles in its implementation. Let us see what the possible obstacles are and what we can do about them.

**Q.2 The first obstacle is the quality of infrastructure. In many schools of our country, infrastructure is far from adequate. Every school must have an ideal laboratory, space for carrying out activities, and mathematics laboratory.**

A.2 That is perfectly right. NCF-2005 has recommended that we must provide access to science experimentation kits and laboratories in rural areas as one of the important ways of equitable provisioning for science learning. It should be ensured that basic infrastructure is available in all schools of the country. For quality improvement, every school must have mathematics laboratory.

**Q.3 It is sometimes said that even without adequate infrastructure, activities and experiments can be carried out, at least up to elementary levels. How can**

**this be done? I feel that we do need tools and space to carry out activities.**

- A.3 What is required is that teachers of a school discuss together and exchange their ideas to design their own tool kits to improvise equipments to carry out low-cost activities and experiments using locally available materials. They can even meet together at the district, zonal and regional levels for this purpose. Even children can participate in the development of the tool kits. Here, one must try to explore the possibilities of sharing the resources. Some specific equipments could be shared among schools if they are placed in the cluster centre.

Children are constantly interacting with the physical environment of their schools during structured or unstructured time, consciously or unconsciously. We need to pay attention to it.

Teachers might utilise every conceivable situation for learning process. For example, on the school's ground certain things are almost always available, such as soil, plants, trees, insects, birds, sunshine and shadows, bicycles and automobiles. A range of activities can be organised from these things, situations and materials. Proper planning is required to encourage participation of children and make their learning effective.

**Q.4 Is it really possible?**

- A.4 Certainly. There are examples where this has been possible. For this, a change in mindset is needed. This is best brought out by teachers coming together.

**Q.5 But even if activities are possible with limited infrastructure, my fear is that I would not be able to complete my syllabus. How should I deal with this problem?**

- A.5 Your fear is natural. But once you start this approach with a little effort, you will observe that learning among students is accelerated. You will begin to devise your own ways of conducting activities/experiments, group work, discussion and brainstorming, and you will be gratified to see the

## LEARNING THROUGH THE PHYSICAL SPACE:

Children perceive their world through multiple senses, especially the tactile and visual senses. A three-dimensional space can offer a unique setting for a child to learn because it can introduce a multiple sensory experience to accompany the textbook or blackboard. Spatial dimensions, textures, shapes, angles, movements and spatial attributes like inside-outside, symmetry, up-down, can be used to communicate some basic concepts of language, science, mathematics and the environment. These concepts can be applied to existing as well as new, to-be-built spaces.

- ✓ *Classroom space:* A window security grill can be designed to help children practise pre-writing skills or understand fractions; a range of angles can be marked under a door shutter on the floor to explain the concept of angles; or a classroom cupboard can be modified to be used as a library; or a ceiling fan can be painted with a range of colour wheels for children to enjoy the ever-changing formations.
- ✓ *Semi-open or outdoor space:* The moving shadows of a flag-pole acting like a sundial to understand the different ways of measuring time; planting winter deciduous trees that shed their leaves in winter and are green in summer to make a comfortable outdoor learning space; an adventure playground could be developed here using discarded tyres; a counter space to simulate a bus/train/post office/shop counter; an activity space for playing with mud and sand and making one's own mountains, rivers and valleys in an outline map of India; or space exploration and discovery; space to explore three dimensions; or the outdoor natural environment with plants and trees that allow children to explore and create their own learning materials, colours, discover nooks and corners; grow a herbal garden; and actually see and practise rainwater harvesting.

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positive outcomes of the approach. You can also consider involving children and older learners in planning the class work. Such a practice can bring tremendous richness in

the classroom. In the beginning, it may appear difficult to manage the class and the time but with commitment, the new approach will begin to yield fruit.

### **Q.6 Performing activity/experiment and carrying out discussion in the class cause disturbance to adjoining**

#### **LEARNING BY DOING**

Maria invites her IX standard students to contribute in the teaching-learning process. In order to involve the whole class and to create 'who is doing what' atmosphere, all the students together form four to five groups and write the name of the group members preparing and presenting an activity/experiment to the class. Students willingly arrange for some materials and apparatus from the school/surroundings. Maria facilitates them in planning and carrying out the activities. Presentation of the activities is followed by discussion on the concepts. Using hands for working leads to a lot of 'how' and 'why' coming up in the mind of the students. Maria says "It makes my job easier as learning is retained by the students. Furthermore, I am very pleased to observe that the students who appear very shy in the class, work actively as a member of a team."

Experience of a teacher

#### **THIS CAN BE ALSO DONE**

Shabana is in-charge of the science laboratory of her school. She makes it a point to display a list of apparatus and materials available in the laboratory on the school notice board. It facilitates children and her colleagues to plan activities and experiments well in advance.

Experience of a teacher

**classes and there is objection from the administration. How can we overcome this difficulty?**

- A.6 This is a genuine difficulty. Like the teachers, the administrators too need a change in mindset. They should discuss with the teachers and arrive at practical ways of

maintaining order and discipline in the school, even when activities/discussions are going on in different classrooms. Teachers and administrators both need to be flexible.

#### LET US DO SCIENCE

Shakti, principal of a government school, has initiated a project in his school. Once in a week, any student or group of students can demonstrate any activity in any subject during recess. They have conducted the activity on formation of bubbles, air occupies space, formation of shadow by different settings of one's palms, testing adulterations in food items, etc. Their names are announced during the morning assembly. Children finish their lunch fast, to observe, interact and participate in the activity which is held on the assembly ground. Many times, students of class VI demonstrate and students of secondary and higher secondary stages also get actively involved in it. Lively interaction is observed during presentation. Though, it is not a mandatory exercise, almost all the students and teachers look forward to it.

Experience of a principal

#### **Q.7 But, there are not enough resource materials for guidance.**

A.7 A number of activities, exercises, ideas for extended learning and projects have been incorporated in the NCERT textbooks to facilitate students to build their knowledge. NCERT is making further efforts in this direction. *Teacher's Handbooks, Science and Mathematics Exemplar Problems and Laboratory Manuals in Science and Mathematics* have been/being prepared. Apart from this, a teacher can do a lot herself by utilising resources available in the library, through Internet and also by interacting with other teachers and by involving parents.

#### **Q.8 It is difficult to get access to the resource materials. What can be done?**

A.8 With some planning and coordination, access to resources can be improved. For example, newspaper, magazines and



electronic media can also be used to supplement classroom teaching. Good educational programmes are aired on various T.V. channels, especially on *Gyan Darshan*. For example, whenever *Rohit*, a teacher at higher secondary stage, watches a good educational programme on the T.V., he informs two of his students on telephone about it. Those two students inform two other students and through this chain of information, the whole class watches the educational programme in the late evening or early morning or on holidays. Later the topic is discussed in the class. Learning is appreciated as participatory process.

**Q.9 We do not have access to innovative curricular materials and ongoing professional support to meet the objectives of NCF-2005. What do you say in this regard?**

A.9 NCERT and various state agencies organise training programmes from time to time for this purpose. You may visit our website [www.ncert.nic.in](http://www.ncert.nic.in). Please refer to **List of Resource Materials** on the inner side of back cover page.

**Q.10 Our efficiency and competence are evaluated on the basis of percentage of marks obtained by our students in the examinations, not on how well they have learnt. Why should we follow the constructivist approach to learning?**

A.10 It is true that most activities in the school are examination driven. When children are involved in active learning in this approach, they are able to perform well in the examinations too, because they learn how to learn. They get self motivated to learn. Facilitating students in studying and relating their learning to their everyday life experiences make the job of the teacher easier.

**Q.11 There is another problem. There is no flexibility in school calendars. This is a real hurdle to implement the constructivist approach.**

A.11 You are right. If you feel the need to bring changes in the school calendar, you should feel empowered to put forth your point of view to the concerned authority with conviction

and in a persuasive manner. NCF-2005 recommends flexibility in school calendar as well as in the timetable. There is a need for providing a few longer periods lasting an hour, or one and a half hours, in the school timetable that allow for other kinds of activities, such as laboratory work, projects, etc. This much length of time is also essential for undertaking across the subjects integrated learning and for effective group work.

**Q.12 What is the meaning of going beyond the textbook and the classroom?**

A.12 Textbook is only a tool of transaction of contents in teaching-learning process. Learners' own experiences outside the classroom and the textbook should be integrated in their learning. It is through interaction with the environment that the child construct knowledge and derives meaning. Therefore, it is necessary to make the boundary between school and her natural world porous. Exploration, inventiveness, field visits and creativity through activities, experiments and technological modules should be emphasised. These should be contextualised, as far as possible, in order to make learning joyful.

**Q.13 NCF-2005 says that for any qualitative change from the present situation, science education in our country must undergo a paradigm shift. What does it mean?**

A13 Any policy of education is based on contemporary ideas on how children learn as well as on a certain understanding of the societal situation around and the need of time. NCF-2005 has recommended a constructivist approach to learning science and mathematics and has strongly discouraged rote learning. It also recommends that schools should give much greater emphasis on various curricular elements, considering them as integral part of curriculum, with an aim to stimulate investigative and creative abilities of children. Areas of knowledge such as heritage crafts, work, the arts, health and physical education, and peace education have very rich potential for the development of creativity, resourcefulness, practical intelligence and teamwork. These should be integrated and interrelated with different subjects. Concerns

and issues pertaining to environment should be emphasised in every subject and through wide range of activities. These principles are not new, but there is considerable change in focus and emphasis. This is the paradigm shift.

**Q.14 Traditional method of teaching also allows for dialogue between the teacher and the learner. What then is the difference between the traditional method and the constructivist approach?**

A.14 In the traditional method, generally the teacher explains the concept, and asks questions having predetermined answers. If learners reply along that way, the objectives of teaching are assumed to be achieved. But in the constructivist approach, due attention is given to the thought process of the learners. Children are involved in enquiry and exploration and develop the concepts by their own experiences. They perform activities and experiments. They are facilitated to connect new ideas to the existing ideas on the basis of material/activities presented to them. The teacher involves the children in all activities of teaching-learning process in order to facilitate construction of their knowledge. She provides them opportunities to express their ideas in their own words about the concept. Their ideas are acknowledged and valued.

**Q.15 How can we provide them opportunities to construct their knowledge?**

A.15 This can be done by engaging them in activities, experiments, projects, field visits, library, discussion with peers and teachers, group work, conducting brain storming sessions, collecting information from different sources, inquiring, listening, thinking, etc. Learners should be allowed to share and explain their ideas, and to ask, raise, pose and frame questions. Teacher can design her own way of facilitating the learners in constructing their knowledge depending upon the situations. For example, they may form different hypotheses for the conditions of rusting. Their opinion may be collected and teacher may design experiments to test their opinions (e.g., iron nails— kept in water, kept in open space, kept in an airtight container, kept coated with some oil, kept in vinegar, and so on, for the same duration).

**Q.16 Can children be trusted to construct their own knowledge?**

A.16 Yes, they can be. They are part of teaching-learning system. Children may be allowed to make mistakes and think independently, and not be ridiculed. They should be encouraged to speak in their own words. Textbook wording need not be repeated. In the beginning, even the incorrect answers of students may be accepted and respected without being judgmental. Gradually, they can be facilitated to validate and construct their knowledge by engaging themselves in various activities. We need to provide opportunity to children to realise that learning to learn and the willingness to unlearn and relearn are important as means of responding to new situations in a flexible and creative manner. Processes of science and mathematics and construction of knowledge should be emphasised at all levels of learning.

**Q.17 Conducting activities and experiments, I face a problem. Only the more vocal students come forward in the discussion of the activity. How can I ensure active participation of all the students?**

A.17 Yes, this is a problem. NCF-2005 says students need to be encouraged to speak up what they think, to explain their answers, to predict if concepts learned earlier are being applied in new situations. Teacher needs to respond to students' thinking/responses in a neutral rather than in an evaluative way. This will encourage students to participate actively in teaching-learning process and explore their own ideas.

**Q.18 How is an activity different from an experiment?**

A.18 Activity is rather a general term, which encompasses various meanings. It is usually open ended with broad and flexibly structured steps. It is carried out in a natural environment. Its aim is to develop various process skills of science, like observation, measurement, making inferences, communication, etc. With the help of an activity, students arrive at some conclusion. Activities are part of learning process. It cannot be taken into isolation.

Activity under controlled situation is experiment. Experiment is more focussed, controlled and structured.

A few of the variables are controlled and their relationship with other variables are explored. There is usually some hypotheses to be tested in an experiment. It often, if not always, involves some quantitative measurement and it aims to verify/confirm some principles of science.

Distinction between an activity and an experiment is not very rigid. At the upper primary and secondary stage, where science is taught with more interdisciplinary approach, teaching-learning process is activity driven. But at the higher secondary level, where different areas of science are taught as separate disciplines, experiments are necessary.

**Q.19 Class tenth and twelfth students are too busy to be involved in any type of activity. Why should we involve them in those activities?**

A.19 We need to convince them that doing experiments helps in learning and retention of scientific concepts better. They need to experience this fact themselves. Once this happens, students will regard experiments as an aid and not a hurdle for their examinations. Further, experimental works are to be integrated with the theory to make it meaningful.

**Q.20 I am not yet convinced. How do activities help to aid learning?**

A.20 Activities aid in learning in many ways. When children perform any activity, they enquire, explore and do things on their own, with their peers or in the company of adults, and use language to express or ask, to listen and to interact with the environment around. They learn the processes of science. Therefore, it helps in understanding the concepts and reduces rote memorisation. At the same time, it minimises stress of children and helps them in enhancing their self-confidence.

**Q.21 Now I am convinced of carrying out various activities during teaching-learning process. But a major problem is how to evaluate students in activities/experiments. How can I do it?**

A.21 This is a very relevant question. First of all, evaluation cannot be separated from learning. It is to be integrated with all teaching-learning experiences. There must be space

and time for students and teachers to plan activities and experiments, discuss ideas and critically record and analyse observations. Oral testing, evaluation of group work, and process skills of science should be in-built part of activities/experiments. How students summarise and record their observations, interpret the data, draw conclusion, participate in activities, set up the experiments, improvise simple apparatus, make models, collect and display specimen of parts of plants, rocks, etc., and get involved into inquiry are some of the parameters for evaluation of activities and experiments. Teachers may also evolve a flexible and implementable scheme to assess a wide range of performance parameters of students for this purpose.

**Q.22 Will it be correct to evaluate an activity/experiment only on the basis of the result obtained?**

A.22 Science is more than the product of knowledge. The process of science is equally important. Different process skills such as observation, classification, measurement, communication, inquiry, manipulation of apparatus, etc., are some of the parameters that can be assessed. Conducting activities helps teacher to spot unique strengths and weaknesses of her students. In fact, activities and experiments provide the basis for ongoing observation and qualitative assessment of children.

**Q.23 This seems to be all idealistic and impractical. My question is how to give marks/grades to students in activities/experiments.**

A.23 Grades should be given on the basis of continuous assessment of the child's progress and accomplishment. The inputs to this assessment may be written reports by the student, teacher's record of the student's work, observation, interviews, etc.

**Q.24 But this is impractical for assessment on a large scale, such as at a Board Examination.**

A.24 The Board's assessment of practical work includes internal assessment, which is carried out by schools. Recently, CBSE has also taken important measures to include written questions in practicals for their examination papers.

**Q.25 NCF talks of diffusing boundaries across different subjects. Please explain about it.**

A.25 This means that we should avoid excessive compartmentalisation of knowledge. In the elementary stages of school education especially, we should adopt integrated approach as much as possible. Even in later stages, boundaries between subjects should not be viewed too rigidly. Natural phenomena do not occur as physics, chemistry or biology. Nor do social issues separate themselves into different disciplines. Every phenomenon or issue has many interconnected aspects, which draws on different subjects and disciplines. This is particularly so in the modern complex technological world.

**Q.26 What is the difference between integrated and interdisciplinary approach?**

A.26 Integrated approach of curricula facilitates students to learn the concepts as an interconnected body of knowledge, not as fragmented piece of knowledge. It helps students to make connection of concepts across the curricula. Students develop life long skills that allow them to think critically and make informed decision about their world. Science upto secondary stage is dealt with this approach. In the interdisciplinary approach attempt is made to design planned learning experiences which provide the learners with a unified view of commonly held knowledge. Subjects are treated with various perspectives cutting across disciplines and forming a new method for understanding the problem at hand. It also equips the learners to develop power to perceive new relationships and create new mental models. For example, lessons on the themes '*Energy*', '*Global Warming*', '*Natural Resources*', '*Our Environment*', have much scope for dealing with interdisciplinary approach.

**Q.27 What does NCF-2005 say about the integrated and interdisciplinary approach to science?**

A.27 NCF-2005 greatly emphasises both. Upto secondary stage, integrated approach is especially advocated. A curricular area like science is not to be seen in terms of individual discipline, like physics, chemistry or biology. At later stages,

these subjects have to be taught as separate disciplines, but there again, NCF-2005 lays great emphasis on interdisciplinary approach.

**Q.28 How is diffusing boundaries across different subjects useful for learning?**

A.28 Knowledge becomes interrelated and integrated to the child by softening the boundaries between different subjects. She constructs her knowledge the way she views the world. Knowledge in the school and outside the school becomes part of her knowledge framework and she is able to apply it in her daily life. Areas of knowledge such as crafts and sports, if integrated, have the potential for development of various skills, and promote aesthetics, creativity, resourcefulness and teamwork.

**QUESTIONS ASKED IN DIFFERENT WAYS**

A question, “What is the colour of this solution” can be better framed as “Tell me about the colour of this solution.” Some other form of open-ended questions may be– “What do you think will happen if.....”  
“Is there another way to.....”

**Q.29 Should we allow the students to answer in different ways?**

A.29 Children answer the same question in different ways if you have not imposed your answer. There is no issue in allowing them; the issue here is accepting their answer and analysing it to see the progress of learning and the direction of learning.

**Q.30 What is continuous and comprehensive assessment?**

A.30 Continuous assessment means assessment of learners in the beginning of instruction, during the instructional processes and assessment of performance done at the end of unit/term using multiple techniques. Comprehensive assessment means all aspects of learning, i.e., curricular areas, personal and social qualities, interests, attitudes, values need to be assessed as well. Therefore, each school should evolve a simple



and suitable scheme that could be developed by it, involving its teachers.

**Q.31 Why is the need for school-based continuous and comprehensive evaluation felt?**

A.31 Its need is felt to reduce stress among children and provide space for the teacher for creative and diagnostic teaching. Diagnostic teaching helps students to learn to detect, understand and correct misconceptions on their own and their fellow students' work. As an experienced teacher, you might always be doing it and might have observed that it provides opportunity to children to develop greater skills. The continuous and comprehensive scheme should be simple, flexible and implementable in any type of school from the elite one to a school located in rural or tribal area.

**Q.32 How can we bring about flexibility in the examinations?**

A.32 NCF-2005 suggests many ways to bring flexibility in the examination. Some of these are creating more opportunities for children to appear in the examination, change in the typology of question paper and a balance between internally and externally examinable knowledge and intellectual skills. There are public as well as internal examinations in our system. It is true that any radical change in large-scale public examinations is not easy; it requires a broad consensus and corresponding policy changes. NCERT is making efforts in this direction. But a lot can be done for the internal examinations within the school by the teachers. Schools should be given internal autonomy to bring about flexibility in assessment in terms of types of questions, time and tests that cater to individual differences.

**Q.33 In order to shift the focus from memory-based learning to higher level competencies, what modes of assessment should be used?**

A.33 You have asked a very good question. Oral testing, group-work evaluation, open-ended questions, open-book examination,

examination without any time limit, on demand examination may be used as various modes of assessment. Besides, the teacher can design her own innovative methods of assessment.

**Q.34 Will the approach to open book examination and similar ideas not be equivalent to cheating?**

A.34 Not at all. For an open book examination, a different kind of question paper is to be set. Such measures would discourage rote learning, one of the guiding principles of NCF-2005, and measure interpretation, analysis and problem-solving skills of children.

**Q.35 Are there any examples of open-ended questions in mathematics?**

A.35 There are plenty. Examples: finding two polynomials such that the degree of their product is 5; finding three or four rational numbers between two given rational numbers say  $\frac{3}{5}$  and  $\frac{4}{7}$ .

**Q.36 What is the meaning of non-detention?**

A.36 Non-detention means a student is not detained in the same class even if her performance in an examination is unsatisfactory. Sometimes non-detention policy is confused with no assessment. Assessment is an integral part of teaching-learning process at all stages of education. Of course, its form may be different at different stages and for different components of the curriculum. NCF-2005 says that up to upper primary stage there should be no detention of students. It recommends taking remedial measures to improve performance.

**Q.37 Will it not dilute the standards?**

A.37 Not necessarily. For this, assessment needs to be continuous and comprehensive. Learner should be assessed during the teaching-learning process. Diagnosis of misconceptions can be done from formative assessment and accordingly remedial measures can be taken. Non-performance is the problem of the system, not of the child. He/she should not be penalised for this.

**Q.38 What is the meaning of the ‘three year window’?**

A.38 It is a time limit suggested to clear the particular public examination as per the pace of learning of different students. In a given year, they may appear in only those subjects for which they are well prepared.

### Examination Reforms

For many students the Standard X year is a time of unremitting stress. Failure in the examination is seen as a major disaster; among the better students, even failure to get sufficiently high marks causes grave anxiety and guilt. From the standpoint of the school, the examination determines the content and methodology of schooling right down to the upper primary level. Thus if we are to conceptualise meaningful reforms in the educational system as a whole, it is essential that we turn a critical eye at this examination and the associated curriculum, syllabi and textbooks.

Whether one assigns marks or grades, one of the most fundamental reforms that must be affected is alternatives to the concept of overall pass or failure in the Standard X examination. The student who cannot make the grade at the examination of Standard X must not have to go through life with the ignominious label “tenth standard fail”. **Schools must be evaluated on the basis of the number of children who have continued their study, not on the basis of their performance in examination.** The 15 or 16 year old in Class X are adolescents; the schools must be ready to engage with them, providing them guidance and counseling as integral part of education.

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(p.22)

**Q.39 NCF-2005 recommends eliminating the term ‘fail’ from the marksheet. Why do we need to remove pass/fail terms?**

A.39 As an experienced teacher you must have observed that the term ‘fail’ carries a social stigma. It amounts to

victimising a child for systemic deficiencies: inadequate teaching, unavailability of textbooks, etc. The term 'fail' may be replaced by 'needs more work to attain desired standard' or 'needs improvement'.

In the public examination there may be some students who do not demonstrate satisfactory completion. They should be provided a number of chances (within three or even five- year period) to retake the examination. Till then they are 'working towards certificate'. Even after expiry of this period, they should be free to attempt the whole examination again. Hence, while it is possible to not succeed in passing an examination, no one ever definitely (and permanently) 'fails'.

**Q.40 NCF-2005 says that the focus should shift to framing good questions rather than mere paper setting. How can it be done?**

A.40 Good questions need not be generated by experts only. These can be pooled all year round, from teachers, college professors, educators from different states, and even students. These questions, after careful vetting by experts, could be categorised according to difficulty level, topic, concept, competency, and the estimated time to solve. A record of these questions can be helpful in generating good questions.

## KEY WORDS AND PHRASES

### Abstraction

The process of developing concepts. In this process, concrete experience is generalised and idealised to form a logical structure. For example, many experiences with four objects produce the concept of a number 4. Similarly, many experiences with boundaries produce the concept of curve and surface.

### Analogy

Considering a similar but slightly different situation. For example, if  $a$ ,  $b$  and  $c$  are positive integers such that  $c=ab$ , then  $a$  and  $b$  are factors of  $c$ . In the same way, for three polynomials  $p(x)$ ,  $q(x)$  and  $r(x)$ , if

$$r(x)=p(x) \cdot q(x),$$

then  $p(x)$  and  $q(x)$  are factors of  $r(x)$ .

### Approximation

Arriving close to a quantity without getting it exactly. For example the square root of 500 is approximately 22. A better approximation is 22.5. But neither of these is actually equal to the square root of 500.

### Argumentation

A process by which something is claimed to be true or false and by giving reason why it is so. Then addressing the question “what if it is false (or true)?” and giving reasons why it cannot be false (or true). Such reasons may again raise new questions, and so on. It is similar to proof but more informal.

### Case analysis

Break up a problem into different cases: for instance, providing different proofs for the cases when  $x < 0$ ,  $x = 0$  and  $x > 0$ , thus showing it true for all values of  $x$ .

## **Children learn to enjoy mathematics**

This is based on the premise that mathematics can be both used and enjoyed lifelong, and hence, that school is best place to create such a taste for mathematics. Children learn to enjoy mathematics if activity-based teaching is done in the class.

## **Conjecture**

Making a statement that we strongly believe to be true, without proving (or disproving) that it is indeed true. For instance, “Every even integer greater than 4 can be expressed as the sum of two odd primes”(Gold Bach Conjecture). This statement has not been proved or disproved so far.

## **Consolidation**

Revisiting a concept that has already been learnt, perhaps with new ideas (as opposed to learning new things) so that foundation is strengthened.

## **Contextualisation**

More autonomy and flexibility in textbooks and syllabi at all stages of school education within the broad guidelines of the curriculum framework. This is because we need to reflect on the diversity of our country.

## **Critical pedagogy**

It is an approach of teaching in which children are encouraged to question, to argue and to debate on the topic being taught. They are helped in forming their own opinions and not accepting theories and practices of the subjects without reflections. Critical pedagogies facilitate collective decision making through open discussion and by encouraging and recognising multiple views.

## **Critical thinking**

It is a mental process of gathering information from all senses—verbal, written, observation, experience, reasoning and reflection. It enables the children to channelise, evaluate, explain and reconstruct their thinking.

## **Curriculum**

All the activities which are planned and guided by school whether it is inside or outside the school. It is a plan for

facilitating learning for the child and coordinating between the aim of education and the child's capabilities. It is neither a document nor a sequence of experiences. It consists of a set of aims in terms of the content of what is to be taught and the knowledge, skills and attitudes that are to be deliberately fostered. It also states criterion for selection of contents and choices in methods, materials and evaluation.

### **Curriculum that is ambitious and coherent**

**Ambitious** in the sense that it seeks to achieve the higher aim of mathematics education, i.e., to develop the child's resources to think and reason mathematically, to pursue assumptions to logical conclusions and to handle abstractions. **Coherent** in the sense that different methods and skills acquired through the study of mathematics, namely, arithmetic, algebra, geometry, etc. can be applied to solve problems of daily life and can also be applied to other subject areas.

### **Estimation**

Determining a quantity without performing detailed calculation. For instance, we estimate the wood required for making doors and windows in a house in terms of number of logs. We often guess the weight of a gourd as "between  $\square$  and 1 kilo" without actually weighing it.

### **Folk algorithms**

Methods employed commonly by people. For instance, the way people estimate the number of mangoes in a tree for leasing. These are relevant and can be of use in schools as well. It exists for not only mentally performing number operations, but also for measurement, estimation, understanding of shapes and aesthetics.

### **Generalisation**

Arriving at a general conclusion through a large number of examples/patterns/situations. For example, by measuring angles of different types of triangles and finding their sum to reach at the general conclusion that the sum of all angles of a triangle is  $180^\circ$ .

### **Good science education is true to science**

It implies that children make attempts to learn processes and facts of science logically, honestly and meaningfully.

**Good science education is true to child**

The phrase means active involvement of children in teaching-learning process of science so that she is motivated for learning to learn.

**Good science education is true to life**

It means that child is equipped with the requisite conceptual understanding of science to apply it in her everyday life situations.

**Heuristic**

The term 'Heuristic' is used to describe an approach to problem solving. It involves 'rules of thumb'. Here those strategies are used which are loosely applicable, which work often but not always. For instance, when we are unable to solve a problem in the general case, a good heuristic is to try a few examples and watch for patterns. To find a property of some triangle, it is often useful to first investigate the special case when the triangle is right angled and then look at the general case afterwards are examples of heuristics.

**Higher aim of mathematics**

It stands for providing adequate opportunities and scopes to students for their intellectual development according to their inherent potentialities. This calls for clarity of thought and pursuing assumptions to logical conclusions and to handle abstractions.

**Innovative alternatives**

Coming up with new methods to solve existing problems.

**Learning environment**

Places where children have an opportunity to learn on their own, at their own pace, according to their individual ability and motivation.

**Mathematical communication**

A specific style and notation is used in mathematics for making statements, and learning. This is useful for consolidating one's knowledge. For example, it is better to talk of an isosceles triangle rather than a triangle whose two sides are equal.



### **Mathematical modelling**

The process of constructing a mathematical model (a mathematical relation that describes some real-life situation) is called mathematical modelling, i.e., a conversion of physical situations into mathematics with certain conditions. The various stages involved in mathematical modelling are formulation, assumption, solution, interpretation and validation. The model is useful in other similar situations also.

### **Multigrade classroom**

Children of different grades, i.e., I, II, III, etc., sitting together and learning their own age-appropriate content by a single or more teachers.

### **Multiplicity of approaches**

Solving a problem by different methods. Many times, a result/problem may be proved/solved in different ways. For example, Pythagoras Theorem can be proved by using the concept of similarity of triangles as well as using the concept of area of parallelograms on the same base and between the same parallels. A system of linear equations in two variables can be solved in different ways. The fact that there are infinitely many rational numbers between two given rational numbers can be estimated by different methods.

### **Multiplicity of textbooks**

In our country, textbook is the only accessible and affordable curriculum resource. Therefore, we must use the textbooks as one of the primary instruments of universalisation of good science in the country. National agencies make efforts to produce quality textbooks. Considering pluralistic and diverse nature of Indian society, different states may also develop multiple versions of the textbook reflecting local contexts. If possible, states may be encouraged to make separate textbooks for different districts.

### **Narrow aim of mathematics**

It specifies the attainment of minimal mathematical literacy so that one can transact his daily-life business along with

social obligations smoothly. It means acquiring mastery of the concepts such as numbers, operation on numbers, measurement, percentages and their application, ratio and proportion, etc.

### **Open-ended questions**

Questions which seeks from respondents to answer in their own words. Here answers are not unique and fixed. It is a contrast to closed questions which demand a specific piece of information or choosing the most suitable choice or selecting yes/no or true/false. Open ended questions are vital for effective teaching-learning.

### **Open-book examination**

It refers to evaluation on comprehension and application abilities of the learner rather than on rote memorisation. It requires thinking about and evaluating the concept and applying it to some new situation. Open-book examination prepares the learner to enter into the world of work. People at work may use reference book or collect information from various resources to solve a problem. Likewise in open-book examination learner is expected to come with some knowledge and understanding. The answer of a question is not available even on a single page of the textbook. Learner is allowed to bring books in the examination hall. Question paper is set in a very typical way.

### **Optimisation**

Finding the maximum or minimum values of a quantity subject to some constraints. For instance, the area of a rectangle with a given parameter of dimensions  $a$  and  $b$  is maximum when  $a = b$ . In life situations, it also involves trade off: for instance, route 1 is comparatively longer than route 2 but has less traffic, so route 1 is preferred.

### **Paradigm shift**

This term refers to a radical change in certain thought patterns. It is a shift from one way of thinking to the other. It does not happen automatically but is driven by some agent of change, e.g., the transition from *Newtonian Mechanics* to *Einstein Theory of Relativity*.

## **Pedagogy**

It is an art as well as science of being a teacher. It is referred to as suitable selection and use of teaching strategies keeping in view the learner's previous knowledge and experiences, learning situations and goals set up by the learner and the teacher.

## **Quantification**

It is fundamental to scientific method. It tells about the quantity of something, e.g. '*every child in the classroom is attentive to the teacher*'; '*the force of gravitation on the moon is one sixth of that on the earth.*' Here '*every*' and '*one sixth*' are quantifiers. Thus it means associating numbers with quantities so that they can be computed. Compare '*Delhi is far away from Chennai*' with '*Delhi is more than 2000 km from Chennai*'.

## **Reflective teaching practices**

A process in which teacher/educator examines her own method of teaching that whether it is supporting in realising the specific objectives, whether it is suitable to the given situations and if not which method will best suit the learners. This is a lifelong and cyclic process in which teacher continues to build these theories, adjust her practices and reflects on her theory and practices.

## **Scientific method**

It is a process of predicting a natural event or phenomenon on the basis of certain principles. It involves several interconnected steps: observation, looking for regularities and patterns, making hypothesis, devising quantitative or mathematical models, deducing their workability, verification or falsification of theories through observation and controlled experiments, thus arriving at the principles, theories and laws governing the physical world. The order of various steps might change according to situations.

## **Spatial reasoning**

Understanding relating the space. For example, locating various objects with respect to given shapes; interior, exterior and boundary of a geometrical shape.

### **Structuration**

The process of structure emerging from patterns (and other mathematical insight). For instance, in algebra, arriving at 'multiplication of a variable by a constant' after observing certain patterns. Different sets of numbers have their own structures with respect to certain operations such as addition, multiplication, etc.

### **Systemic reform**

Every system has its own strengths and weaknesses. Reforms, which help a system to correct its weaknesses, are termed as systemic reforms. Every system works in coordination with other systems linked to it, e.g., school system works in coordination with examination and teacher education system. So when we talk about bringing change in our assumption about child, learning, teacher and teaching-learning process, we need to take into cognizance the fact that until change or reform takes place in examination and teacher preparation system, it is difficult to bring reforms in school system.

### **Systematic reasoning**

Proceeding from assumptions to conclusions in a logical manner, without extraneous matter. The aim of systematic reasoning should be to develop arguments, make and investigate conjectures and understand that there are various methods of reasoning.

### **Teaching important mathematics**

The phrase implies that whatever mathematics has to be taught, should be based on the needs of the students, society and the subjects, i.e., need-based mathematics. Students and teachers must find sufficient reasons and relevance for the topics to be taught.

### **Teacher expects to engage every child in class**

Removing fear and phobia regarding learning of mathematics and science and making these subjects so interesting that every child is encouraged to participate in teaching-learning process.

**Validation procedure**

Validation procedure in mathematics is demonstrations which are integral to the system. It is specified by an appropriate set of axioms and definitions. For example, different concepts in mathematics are prime numbers, square roots, fraction integers, function, etc.

**Validity**

Features in the curriculum which are essential to make it good and meaningful.

**Visualisation**

Drawing a picture to reflect a situation. The number line, graphs of functions, Venn diagrams, graphical representation of data in the form of pie chart, histogram and frequency polygons are commonly used examples.

## EXAMPLES AND ANECDOTES

Most of the examples and anecdotes given below are from real-life situations. Teachers had conducted classroom activities in the following manner and received good results in terms of learning and performance of the children. They also observed that their relationship with children got strengthened. These examples and anecdotes are suggestive, not prescriptive.

### UPPER PRIMARY STAGE

#### 1. Let us Learn about a Cell

The teacher had to start the unit on 'Cell'. She introduced the unit by making the students observe stained slide of onion tissues through microscopes. She guided her students in taking epidermal peels from the swollen leaves of onion. During this activity, students also viewed slides of other plant tissues and animal tissues. Students were curious to know many things about the cell. Till then the teacher had not used any technical word like protoplasm, nucleus, etc., except 'Cell'. She instructed the students to observe the slides and to jot down the questions that they wanted to be answered. Some of the questions that they came up with were—*“What is the dotted dark structure, at the centre?” “Why is stain not uniformly absorbed by the cell? Why is there no gap between two cells? What is the function of the boundaries around each cell?” “Why plant cells need cell walls?” “Do onion of bigger size have bigger cells?” “Do bigger fruits and vegetables have bigger cells? Are all living organisms made up of cell?” “I have heard the name of gene. What is the function of gene?”* Soon she found students discussing among themselves and framing questions that needed to be answered. Stage was set up for learning from first-hand experience. She started the lesson on the 'Cell' with the queries of children. Students wanted to reinforce their learning and requested their teacher to let them observe the slides again.

## 2. Perimeter

The teacher managed for a doll house in the class to make the lesson on Perimeter interesting to her students. One of the students had volunteered to bring her doll house to the class. She made a number of different figures like rectangles, squares, triangles from a paper sheet equal to the size of the various rooms/windows/roof of the doll house and wrote the name of the room/window/roof like drawing room, bed room, window no. 1, 2, etc., with the help of students. The teacher asked them to measure the length and breadth of different figures using a metre scale, then to find the sum of all sides of that figure. Students started working in groups. They recorded their observations in tabular form. Students of different groups discussed among themselves about the activity and shared their observations. It emerged from the discussion with the teacher that *distance around a closed figure is named as its perimeter*. Thus the perimeter of different rooms of the doll house was calculated. One of the students asked, "*can we make a figure of any desired shape from this sum?*" Teacher suggested her to try out on her own with the help of her friends. The teacher asked them to calculate area of each room of the doll house by multiplying length with breadth of the given paper sheet. Later, the class was taken to the school garden which was square in shape. Students measured its one side as 20 metre. Teacher asked them to find how many metres of fence would be needed to enclose the garden. Later, teacher provided rectangle, square and circle having equal perimeter and asked the students which shape will have minimum area.

One student asked how can we measure perimeter of a circle. The other student suggested that length around the circle, i.e, its circumference is the perimeter of the circle. She made a circular card and marked a point on its edge. A point was marked on the table also. She rolled the card starting from the point on the table along a straight line till the marked point on the circular card again touched the table. This point on the table was then marked. Students measured the distance between the two marked points on the table as circumference of the circle. Another student suggested that perimeter of the circle is the distance along the edge of the circular card from the marked point back to the marked point.

Here students constructed their knowledge on perimeter and area on their own. Teacher provided the learning environment for it.

### 3. Parts of a Plant: Experience of a Teacher

The Class VI Science teacher entered the class with an objective to interact with children about forms and functions of various parts of different plants. She initiated the discussion by asking children to tell something about plants and trees they are aware of. *Peepal, Banana, Jamun, Rose, Mehndi*—tens of names reverberated in the classroom environment. When this buzzing faded out, another leading question from the teacher initiated thinking among children. This was about different parts of plants. The teacher advised children to form small groups and discuss and note down important points about various parts of the plant and their functions for group presentations. Children began to work. Soon the bell rang, indicating the end of the day.

Next day, the teacher began the class with group work and asked the children to present their work after the discussion was over. Each group presented a number of points about structures and functions of different parts of plants. A few of them tried to relate the structures and functions with their own day-to-day life experiences. For example, one child said, *“leaves are the ‘kitchen’ of plants and the roots are suppliers of basic ingredients”*. The other child asked, *“How does a plant get proper nourishment like water, sunlight, etc., for standing erect and strong?”* Another child asked, *“If we do not eat proper food, we fall sick. Do plants also fall sick?”* A few of them were eager to share stories about plants and one child recited a poem. The teacher listened, observed and facilitated the discussion when and wherever necessary. The discussion continued about plants with lively participation of the entire class. Children from tribal backgrounds shared their knowledge and information about plants with other children. However, the teacher noticed that two children were not concentrating in the class. She went to them and asked for the reason. She found that one was suffering from fever and the other had lost her pencil box. She took due care of them and the class progressed. The next day the teacher took the help of the textbook. She raised some questions and gave them a few exercises. All the children had something to say in response. Many raised related and thought-provoking questions. The teacher was so inspired that she arranged a period for taking the class to the garden and also to the library. In the garden, the children themselves observed



and gradually found solutions to their queries. Then children offered the teacher a suggestion that they will make a drawing of different plants, structures of its various parts, etc. The teacher agreed to assign that as homework. The next day the whole class was full of colourful charts and posters. The class was brimming with the joy of understanding the children had experienced in this 'lesson'. A 'lesson'? No, in fact it was an interaction.

"When will you set a test from this lesson?" a child asked out of habit.

"Do you need time to prepare?" the teacher smilingly asked.

"This time I feel I do not need to cram."

"You don't need any test. All of you have understood the topic and have done well".

The child also smiled.

Now, let us analyze what has happened in this class?

- The teacher provided space to children's experiences, questions, and queries and tried to relate them with school knowledge.
- She observed each and every child in the class for her progress in learning. She evaluated her children during the course of the study.
- Once learning got connected with children's day-to-day life, they themselves felt no need for rote memorisation.
- The teacher did not stick to a programmed timetable but showed ample flexibility with regard to time. She was wise enough to make extra time for visits to the garden and library and for detailed discussion. She could successfully convince the school authorities and her colleagues for doing this.
- Children talked about social issues, listened to stories and recited poems, thus going beyond the textbook. The concerns of arts, health, and peace, etc., got integrated in the class without much effort.
- Every child had the taste of understanding. She learned a lot about different parts of plants interacting with the teacher and her peers.

Do you think such a method will help each child learn with ease and joy? Now, do you think it is difficult for you to implement all the five guiding principles of NCF-2005 discussed here in your class?

## SECONDARY STAGE

### 1. Concept of $\pi$

Mathematics teacher asked her class to bring a few colourful chart papers and thread for her next period. Students were curious to know the purpose of it. Next day teacher asked them to cut the chart papers to get 20 circles of different diameters. Students measured circumference and diameter of the different circles with the help of threads and scales. They were working in four groups. Each group was asked to calculate the ratio of circumference of the circles to its diameter and record the value in an observation table. The teacher then told them to compare their findings with that of other groups. Students were surprised to observe that the value of the ratio was very similar in each group. Students exchanged their circles and repeated their observations. They observed that the ratio of circumference of the circle to its diameter was between 3 and 4, approximately 3.14 irrespective of the size of the circles. Teacher asked, ‘*Do you see any relation between circumference and diameter of a circle?*’ She then discussed about  $\pi$ . Arriving at the constant value  $\pi$  as the ratio of circumference to the diameter was very satisfying, both to her and her students.

### 2. A Visit to a Water Supply System

The teacher took her class to a Municipal Water Supply System nearby. The class was instructed to observe and take notes and was encouraged to ask questions. They prepared a worksheet containing questions written on it and space provided for the answer. Some of the questions prepared with the help of students were “*How sedimentation process help in cleaning water?*” “*How biological inputs like bacteria, algae, fungi, etc., are removed?*” “*How water is disinfected?*” “*How much water is used per day in the nearby locality?*” “*Draw a figure of the pump that you observed.*” They were happy when their queries were satisfied by the authorities working there. After their return, they prepared a working model of the water supply system. A poster competition was held on ‘*Conservation of Water.*’ A few students prepared a report of the various steps involved in the purification of water. One group dramatised the process of water purification. Students of other groups performed a dance wearing dresses attached with

brown paper strips and white paper strips to represent dirty and clean water. The teacher facilitated her students to organise and summarise their learning on water supply system.

### 3. Boiling Point of Water

The teacher helped her class to form six groups to perform an activity on determining the boiling point of water. Each group was provided a beaker and different samples of water (such as distilled/tap/pond water, water with some salt/sugar/milk added to it), a thermometer and a gas burner. Students were asked to heat the water samples and note down the readings in the thermometer as soon as it started boiling. They were surprised to observe their results. Each group had found different values of boiling point! They were happy to discuss among themselves and with the teacher the possible reasons for this difference. They observed that boiling point of water (solvent) is increased if solute is added to it. Children were dynamically engaged with the learning process through observing, reflecting, enquiring and sharing.

### 4. An Afternoon on a Sea Beach

One day the teacher took her students to the sea beach. Observing students moving in different directions to explore the things around the sea, she got worried for their safety. She got an idea of utilising the curiosity of the students. She helped them in forming eight groups so that they could choose some interesting projects to do as given below:

**Group 1:** Calculate mean time of waves reaching on the seashore.

**Group 2:** Estimate the dimension of the boats; talk about it with fishermen/fisherwomen and compare with your estimation.

**Group 3:** Talk to the fishermen/fisherwomen about their work; fishes; their profit and loss; their economy; the season for which fishes are available in plenty; and the way they manage their home economy.

**Group 4:** Watch fishermen/women catching fishes, the tides of wave, the sky, reflections of the sun in the sea, etc., and write poems, essay on the topic of their choice.

**Group 5:** Collect songs and stories from fishermen/women and sing with them.

**Group 6:** Observe crabs, tortoise and other living beings, their motion and habitat.

**Group 7:** Make sketches of the natural beauty of the sea and its surroundings.

**Group 8:** Calculate speed of the wave by estimating distance from the place of observation.

After coming back to school, each group presented their report in the class. They learnt to share their experiences and in this activity, everybody enjoyed their learning.

Teacher attempted to dissolve boundaries between different subjects, i.e., maths, science, literature, arts and aesthetics.

### 5. Can You Help Geeta

Geeta's father is a vegetable hawker. One day she went to the market with her father. They had Rs 1000/- with them. They found that a variety of vegetables were available. Rates of different vegetable were:

Potato - Rs 20/kg; Onion - Rs 12/kg; Tomato - Rs 25/kg; Cauliflower - Rs 40/kg; Carrot - Rs 20/kg; Lady's finger - Rs 24/kg; Bitter gourd - Rs 32/kg; Cabbage - Rs 22 kg; Spinach - Rs 15/kg; Gourd - Rs 18/kg.

Can you help her in deciding:

1. What factors should she keep in mind to get maximum profit?
2. Which vegetables should she purchase to get maximum profit margin?
3. In which vegetables profit margin is likely to be low? How?
4. In which vegetable profit margin is likely to be highest? How?
5. Which vegetable will occupy largest volume in 2kg?
6. Should she purchase different quantities of different vegetables for easy loading and unloading?
7. How much weight would she be able to carry on her head?

This situation may initiate group discussion in the class. These open-ended questions may be a challenge for learners at the secondary stage.

### 6. Electricity and Magnetism

A week before the scheduled date of the chapter, the teacher facilitated her students in identifying six subtopics in Electricity and Magnetism. She helped the class in forming six groups. Each

group selected subtopics of their choice to work on as a project. They had freedom to plan for any activity or experiment; make models or charts; collect information from encyclopedia; internet or from the magazines; conduct interviews; solve numerical problems; write and do one-act play or write a poem. The teacher negotiated this project with her students in an arrangement period assigned to her. A week later, the lesson was introduced to the students by asking leading questions based on various sources of electric current they were aware of. An activity of glowing a torch bulb by an electric cell was performed by students with the help of the teacher. They identified transformation of chemical energy into electric energy.

Each group then gave presentation on their projects with their teacher acting as a facilitator. Teacher ensured that all members of the group participate in the presentation.

### **Group 1**

#### **Subtopic—Source of electric current and its historical background**

Students made charts describing construction and working of voltaic cells, dry cells, button cells, rechargeable cells. Some of the students collected a few of the above cells, which they demonstrated in the class. They gathered information about specific uses of these cells. The group also collected interesting anecdotes about scientists (Thomas Alva Edison, H. C. Oersted and W. Nicolson) and their work related with the topic and prepared a historical background of chemical and magnetic effects of electric current.

### **Group 2**

#### **Subtopic—Ohm's law**

Students performed experiment for studying Ohm's law with the help of the teacher.

They drew circuit diagram on the blackboard to show the symbols of electric components. Students observed and recorded the ammeter and voltmeter readings. The relationship between the potential difference across a conductor and the electric current passing through it was discussed by plotting a graph.

### **Group 3**

#### **Subtopic—Judicious use of electricity**

The group prepared a scrapbook, which had clippings from newspapers and magazines highlighting judicious use of

electricity. They also pasted print advertisement of energy efficient electric gadgets. The members of the group carried out interviews/ discussion with the elders in their families/ neighbourhood about the life styles of their childhood without electricity and how their life changed after supply of electric current started in their localities.

The group, with the help of the teacher conducted a “speed test” on calculation of monthly electricity bill using simple formula-

$$\text{Power consumption} = \frac{\text{Power in watt} \times \text{Time in hour}}{1000} \text{ kW h}$$

1000 kW h = 1 unit

Electricity Bill = Power consumption Rate per unit

The group also enacted a ‘play’ during the school assembly on how to reduce wastage of electricity.

One member of the group composed a poem in Hindi on ‘*Bijli Bachao*’.

#### **Group 4**

##### **Subtopic—Magnetism and electromagnet**

The group prepared a working model of an electromagnet using a long iron screw and enamelled copper wire and identified the relationship between electricity and magnetism.

A brief reference on magneto-therapy was given by one of the members.

#### **Group 5**

##### **Subtopic—Earth as a magnet**

The group located north-south direction of their classroom with a magnetic compass needle. During recess, they went to other classes in the same corridor and then to the classes at corridor in perpendicular direction to establish north-south direction there. They prepared a map of different classrooms indicating north-south

#### **STUDENTS ENJOYED PARTICIPATORY LEARNING**

The teacher observed that each of the students of her class had worked on their assignment. When the teacher turned to leave the class after students’ group presentation was over, she heard an otherwise quiet and introvert girl saying, “Mam, today I really enjoyed learning.”

direction there. Using a magnet, iron filings and a drawing board, they mapped magnetic field lines under the guidance of their teacher. They drew a diagram of magnetic field line patterns on a chart paper. Two members of the group had collected information from library and the internet about the magnetic properties of the earth.

### **Group 6**

#### **Subtopic—Electromagnetic induction**

The group performed an activity to demonstrate how electric current is observed when a magnet is quickly moved through a coil connected to a galvanometer or the coil is quickly moved around the magnet held stationary in hand. They repeated the activity by moving the magnet slowly within the coil. Observing very little deflection in the galvanometer, they discussed the reason for it. They prepared a chart to explain the experiment.

Teacher facilitated each group of students to exchange their assignment with other groups. All students had got an opportunity to develop a background on the topic to express their ideas about the concept.

The teacher as well as the class asked many questions in between the presentation.

## **7. Air Pollution**

The teacher familiarised herself with the knowledge of her students on the effect of air pollution with some introductory questions. She then guided them to perform an activity to observe particulate matter (chalk particles) in the classroom by patting the blackboard duster on the table. She allowed the students to ask questions on various aspects of air pollution. The teacher felt that students of her class were quite familiar with this topic. She discussed with them on the design of their assignment work. She helped the students in forming five groups to carry out work on the issues of pollution. She made it clear to her students that if they thought of something different related to the topic, they were welcome to discuss with her.

### **Group 1**

#### **Sources of air pollution**

Identify various sources of air pollution that you think might be reason for it. Suggest ways to minimise it. Prepare and present a report on it.

## **Group 2**

### **Acid rain**

Visit the library/internet to collect the information about acid rain. What causes it? Study its effect on aquatic life, soil and historical monuments. Talk to the monument authorities about the steps taken to minimise the effect of acid rain. Suggest ways to minimise its negative effect. Prepare and present a report.

## **Group 3**

### **Smog**

How does smog pollute the air? What causes it? What is its effect on various modes of transportation? Why does its formation increase during winter season? What are the ways to minimise it? Prepare a report of your own observations and experiences about smog. You may use newspaper clippings, photographs, etc., for illustrations.

## **Group 4**

### **Harmful effects of air pollution**

What are the harmful effects of air pollution on health? How does it affect respiratory and circulatory system of our body? Do pollutants affect the respiratory system of the animals as well? Identify various diseases occurring due to air pollution. Conduct an interview with a doctor regarding this issue. Prepare in advance

### **THE REPERCUSSION: INCREASING INTERACTION**

Students started interacting among themselves and with other subject teachers. Students from other sections came to the teacher requesting to teach them using the same approach. Even interaction among teachers also increased.

the questions that you would like to be answered by the doctor. Collect information through various sources such as television, library, internet, newspaper, etc., What steps should be taken to minimise the ill effects of air pollution on health?



## **Group 5**

### **Collecting and presenting data**

Collect data on various air pollutants in your city. Prepare a pie graph/bar graph depicting their presence in percentage.

Each group prepared a record collaboratively. The group leader presented the report to the class with the help of his team members. The teacher reviewed the concepts whenever required. She did not appoint the group leader, the group selected the leader themselves. Later, one of the students read out a brief report about their findings in the morning assembly of the school.

## **HIGHER SECONDARY STAGE**

### **1. Derivatives**

The lesson was introduced with some observations from everyday life situations. Teacher cited an example that people maintaining a reservoir need to know when will the reservoir overflow knowing the depth of water at several instances of time. Students realised that in order to know the time of overflow of a reservoir they needed to know how one parameter (say height) varies with another parameter (time). The teacher helped them to evolve the concept of rate of change of height with respect to time. She discussed the importance of derivatives of functions and the concepts of functions and limit with the students.

Definition of derivatives of a real valued function  $f$  at a point in its domain was developed through interaction with students. First principle of derivatives was also developed through discussion with students. Derivatives of different functions were explored. Algebra of derivatives of functions was discussed. Teacher facilitated the class in forming small groups and solving the problems based on derivatives.

### **Group 1**

Discuss motion of a body under free fall. Draw a figure showing variation of distance with time for an uniformly accelerated motion. Calculate velocity and the acceleration of the object at different instants of time graphically. You may refer (pp. 43–45) Physics Textbook for Class XI (NCERT 2006).

### Group 2

Collect data regarding population of your state for the last 20 years from the Internet. Plot a graph between time (in years) and population.

Calculate rate of increase/decrease in population.

### Group 3

Visit the website <http://earthtrends.wri.org>.

- Calculate the rate at which landmass is under threat of submerging under seawater from 1961–2000. Record your observations at least five times at equal time intervals.
- Predict the rate of submergence of the landmass for next 20 years.

Present your results using graphs.

At the end students solved the problems individually and shared the methods used by them in solving the problems with each other.

## 2. Radioactivity

The teacher talked to the students about the various resources of information about the accidental discovery of radioactivity by A.H. Becquerel and the works of M.S. Curie. The lesson was started with a brief description of their work. Students discussed '*Law of Radioactive Decay*' with their teacher. The teacher, then facilitated the class to form four groups. Students took up the activity of their interest. Each group chalked out their plan of action with the help of the teacher.

### Group 1

Students conducted an analogous experiment by counting the number of water drops falling per minute from a burette fixed on a stand. Students plotted a graph showing its exponential nature and calculated decay constant and half-life time.

### Group 2

The group identified Actinoid elements of the *f* block from the periodic table. They discussed the reason of these nuclei being unstable, the process of alpha, beta and gamma decay and their properties with the help of a chart, the group had made. Various uses of the three rays were also discussed.

### Group 3

The group collected information from the internet about the medical uses of different radioactive rays such as in the treatment

of cancer, sterilisation of surgical instruments, preservation of foods, etc. Two members of the group conducted an interview with a doctor about the uses of radioactive isotopes in the diagnosis and treatment of various diseases.

#### **Group 4**

The group gave a presentation on the application of radioactivity in determining age of the rocks, age of historical paintings and age of fossils.

#### **OUT OR IN THE MIND?**

When the lesson was completed and discussion was over, a student said, “the concepts of Radioactivity are very clear to me, now. They will not go out of my mind like other chapters went.”

#### **Group 5**

The teacher ensured seeking participation of all students in setting goals and taking decisions. All students had opportunities for collaboration. Later, the teacher employed a buzz session of fifteen minutes to review the concepts. Students were allowed to talk among themselves about what they had learned. They were then ready to answer the questions asked by the teacher.

### **3. Habitats of Different Forms of Life**

Teacher initiated the discussion on the habitats of different forms of life. They began raising questions about how different forms of life could survive in extreme conditions. Teacher suggested them to form six groups and find information from the various sources about the habitat of different forms of life at different places. The previous day she had asked them to read books from the library, visit relevant websites, enquire from their parents and elders on this issue. Students volunteered themselves to work in the area of their choice:

**Group I** Conditions prevailing in scorching heat in the deserts of Rajasthan.

**Group II** Physico-chemical and biotic conditions in rain-soaked Meghalaya forest.

- Group III** Abiotic and biotic components under deep ocean trenches .
- Group IV** Resources and life at permafrost polar regions.
- Group V** Life existing in thermal springs.
- Group VI** Microbial forms in stinking compost pit and our own intestine.

Later the groups shared their findings and requested their teacher to plan for an excursion trip to the nearby village. It provided them an opportunity of very lively interaction among themselves. After coming back all Groups gave a presentation in the class. When Group V presented their observations regarding the existence of life in thermal springs, many queries arose, “*If microorganisms can exist in hot water, is there any chance of getting infection from hot springs?*” “*What happens to organisms when food items are cooked?*” “*If they are killed, how do they survive in thermal springs?*” This led to a discussion and understanding about the concept of ‘adaptation’.

#### **4. Acids, Bases and Salts (Same Concept, Different Stages)**

This topic is dealt with at all the three stages of learning i.e. upper primary, secondary and higher secondary stages of school education.

##### **Upper primary stage**

*At this stage objective is to distinguish between acids, bases and salts on the basis of colour change of the indicator.*

There were two classroom situations to realise the first objective: *Situation (A).* Teacher lectured everything whatever students were supposed to learn. She told about the change of colour of the indicator verbally. She conducted an activity taking dilute acid, base and few litmus paper herself. Class silently observed it.

*Situation (B).* Teacher first asked some questions related to the taste of some edible items. She then conducted an activity taking lemon juice and litmus paper. Observing the change in colour of litmus paper, students suggested use of other substances such as vinegar, tomatoes, apples, orange, baking soda, soap solution and tap water for performing the

activity. Teacher encouraged them to perform the activities in small groups and present their findings to the class. Working with different substances, soon they were able to distinguish between acids and bases. Teacher helped them in drawing conclusions from their observation.

In which of the situation do you think construction of knowledge was facilitated?

### **Secondary Stage**

*At the secondary stage the objective is to relate acidic and basic nature of the substance with the molecular structure of the substance.*

The teacher elicited the response from the students about the role of various acidic and basic substances in human bodies, agricultural fields, different industries and some other living beings. Gradually she introduced the concept of pH. Learners performed activities to find out pH of solutions of various substances of their interest. The teacher then provided different substances to check their pH. In order to discuss the concepts of strong and weak acids, dilute and concentrated acids, first the pH of solutions of different acids of the same concentration were taken and then after diluting those samples of acids to some other concentration, their pH was checked.

### **Higher Secondary Stage**

*At the higher secondary stage objective is to solve problems related to acids, bases and salts. They are aware of the concept of molarity of solution.*

Teacher guided her students in solving numerical problems. They were asked to calculate the pH of different concentrations of a given solution. The class was given to calculate pH of 9M solution of hydrochloric acid. Calculating according to definition of pH, they got the result as -9. They had got an anomalous result. Students discussed various possible causes of anomalies with their teacher and modified the formula for calculating pH.

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