Science Utsav 2019

Proceedings of One Day Teachers' Conference on

Subject and Pedagogical Content Knowledge in Science Teaching

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Organised Jointly by

Navi Mumbai Science Foundation, Vashi

In association with

Shree Gujarathi Samaj, Vashi

and

MAHARASHTRA ACADEMY OF SCIENCES,

MUMBAI CHAPTER

Navi Mumbai Science Foundation[

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Navi Mumbai Science Foundation (NMSF) is a science led NGO inIndia which is dedicated to development of “scientific temperament “ in society in general & the student community in particular. This in turn will contribute towards the holistic development of the nation & prepare it to face the challenges posed by a technologically advancing global environment without losing sight of its societal commitments.

VISION

- Kindle and nurture scientific temperament in students;
- Enhance soft skills like problem-solving approach and communication skills;
- Promote ‘Pupil-centric’ approach in education;
- Create awareness in public about science and scientific issues;

MISSION

To advance, popularize and promote the cause of science in Navi Mumbai.

ACTION PLAN

- **Develop a network** of professionals and personalities to share their knowledge;
- **Provide multi-disciplinary environment** to students to understand their inter linkages;
- **Provide a platform** for interaction between leading educationists, teachers and students;
- **Encourage participation in** scientific activities like:
    - National Children’s Science Congress: NMSF is in charge of Navi Mumbai region
    - (August – November) includes workshop for students and teachers
    - Guidance for Homi Bhabha (March – September) 50 lectures in the week ends
    - Guidance for Regional Mathematics Olympiad. (November – August

- 40 – 50 lectures through the vacation period
- World Nuclear Energy Day (2nd December) : In commemoration of the day the first nuclear reactor went critical.
- Essay Competition: Nurturing talent on Nobel L (June – September)
  Inspiring children with the achievements of the giants
- Fun with science associated with Science day. (February)
  Scientific principles through fascinating demonstrations
- Science Utsav: Teachers' conference (Day One) : Meeting of teachers and researchers on chosen topics of interest to high school education
- Science Utsav (Day Two) : Students exhibition of experiments - Away from the project and models, students get a step forward to present their experimental skills.

Create links with national organizations in the field of science and science education;
Arrange discussions on scientific topics of current interest and publish scientific articles in local papers and magazines.

ACHIEVEMENTS AT GROUND LEVEL

*About **2500 students & 250 teachers** are now being reached through these activities each year.*

IN SHORT, WE AT NMSF, ENDEAVOUR TO

Give meaning to science in ways more than one, and
Erase the artificial barriers that keep science away from the main stream of life.

OUR INDEBTEDNESS

We are indebted to several schools & colleges, a few institutions and a large number ofindividuals, who have been active partners in our activities year after year.

For more information, please visit our website at: ***http://www.navimumbaisciencefoundation.org***

List of Scientific Activities

being Organized by NMSF at Navi Mumbai

I. National Children's Science Congress (NCSC) Activity (supported by Dept. of Sc. & Tech., Govt. Of India).

II Homi Bhabha Bal Vaidnyanik Competition [HBBVC] (Interactive Guidance Sessions for examination by Scientists & Research Scholars)

III. Pre-Regional Mathematics Olympiad (Pre-RMO) and RMO Examination

IV. Science Nurture Club activity for students of Std. VII & VIII.

V. Essay Contest "Nurturing Talent for Nobel Laureatism" for Students of Std. IX & X.

VI Special Event: World Nuclear Energy Day-17 celebration.

VII. Signature Event of NMSF: "Science Utsav ".

VIII. National Science Day related "Fun with Science" Programmes

IX. Judging at Science Exhibitions.

X. Miscellaneous: Partial involvement in Scientific activities of schools: via lectures and / or interactive sessions on specific topics.

MAHARASHTRA ACADEMY OF SCIENCES

[Regd.Soc. No.1020 Pune, Public Trust No.F-842 Pune]

[**Mumbai Chapter**]

{B-51, Gitanjali, Plot No.52,Sector-17,Vashi, Navi Mumbai-400703}

The Maharashtra Academy of Sciences (MASc)is the premier scientific learned society of the state of Maharashtra. It was established in 1976 with the specific aim to highlight the scientific and technological issues confronting the state, and to recommend appropriate steps necessary to be under taken by the concerned authorities for the promotion of science and technology.

The academy has very wide spectrum of interests and has scientists of eminence as its fellows in all the major scientific disciplines. The list of fellows includes eminent scientists in Maharashtra and some outside the state who are interested in the promotion of science and technology and have in particular special attachment to Maharashtra. It has also fellows from industry who have made a name in their respective fields. The fellowship of the academy is conferred upon senior scientists after a peer-group assessment based on their scientific achievements as is practiced in the national academies of India and in the prestigious academies abroad. The first President of the academy was Dr. H. N. Sethna, the then Chairman of the Atomic Energy Commission, who guided the deliberations of the academy in its formative stages.

The academy besides promoting science and technology addresses various issues related to the development of Maharashtra in the areas of: Education, Industry, Communication, Mass Transportation, Agriculture, Natural Resources, Medical & Public Health Services, Demography, Urbanization, Rural Development, Human Resource Development Management and Public Administration, Economics.

Some of the activities undertaken by the Academy so far include the following:

- Presentation of recommendations for the education of groundwater resources of the state.
- Assessment of the impact of the Thal-Vaishet fertilizer complex on the Alibag Magnetic Observatory.
- Presentation of geological sites in the state.
- National seminar on Biodiversity and sustainable developments.•Celebration of the century of the discovery of X-ray and of radioactivity at various places.
- Sc education discussions from time to time & publication of detailed report in the book form by Dr. M. R. Bhiday.
- Several seminars on important topics and lectures by eminent scientists.
- Seminar on “Plastics: Bane or Benefactor”

Additional Activities of MASc (MC)

MASc (MC) is organizing several activities on a regular basis & some occasion-based as required. They are all in association with Navi Mumbai Science Foundation mostly, local colleges, schools & research organizations.

Some important ones are listed below:

- An annual event "Science Utsav" (having 2 parts: Sc. Exhibition for School Students & Teachers' Conference)
- World Nuclear Energy Day: A novel annual event (on Dec. 2, each year)
- Regional Mathematics Olympiad Guidance sessions.
- Homi Bhabha Bal Vaidnyanik Competition Guidance Sessions.
- Science Nurture Club for students of Std. VII & VIII.
- National Children's Science Congress Activity for Navi Mumbai region.
- Fun with Science programmes.
- Throwing Light on Light on Feb. 12, 2016-A half Day Meeting.
- Feeling the pulse of pulses on Jan. 19. 2017- A One Day Meeting.
- One-day meeting on "Functional Materials" (2018) - A One Day Meeting.

At present, there are more than 900 Fellows of the Academy covering the disciplines of Physical Sciences, Chemical Sciences, Earth Sciences, Life Sciences, Medical Sciences, Mathematical Sciences, Agricultural Sciences, Social and Educational Sciences, Engineering and Technology, Economic Sciences, Management Sciences, Computer and allied Sciences and Environmental Sciences. There is also a provision for making honorary fellows, patrons, associate members, young associates, donor members, corporate members and industrial members. The academy is now planning in a major way to welcome in its fold Indian scientists residing abroad, who are specially interested in the welfare of Maharashtra.

Young Associateship: An Overview

The MASc has introduced a new scheme for inducting "Young Associates" below the age of 40 from year2006-2007. This scheme is mainly directed towards young, active and dynamic researchers and teachers as also individuals engaged in activities associated with popularizing and promoting various aspects of science covered by the Academy.

The main criteria for selecting individuals under this scheme are as follows:

1. Age: between 25 and 40 years.

2. The individual must be currently engaged in the activities such as research and development, setting up of new and novel facilities for conducting science and technology related projects, popularization of science, spreading scientific temperament by writing popular scientific articles and development of new and novel techniques for teaching science at various levels.

3. The candidate must have demonstrated his/her outstanding contributions to the above activities with proven records.

4. The candidate to be nominated must have a post-graduate degree from a recognized university in the faculties covered by the academy (or a bachelors degree in engineering with more than 10 years teaching experience).

Navi Mumbai Science Foundation
Science Utsav: Teachers' Conferences

Glimpses of the topics covered during previous Teachers' Conferences…

Year 2019
Main Theme: Subject and Pedagogical Content Knowledge in Science Teaching
Sub-themes:

1. Understanding our learners
2. Learning Environment in the Classroom
3. Role of Subject Matter Knowledge in teaching science
4. Teaching Strategies for Science

Comment: For earlier years, can we mention only the main theme ? The details (subthemes) look somewhat unnecessary.

Year 2018
Main Theme: Moving towards a better understanding of the environment
Sub-theme:

1. Environment related projects undertaken by the schools/teachers/students: Students' ideas on environment related concepts:
2. Relationship between students' background (gender, place of stay, region, cultural background) and environment related issues:
3. Evaluating students' awareness about the environment over the schooling years and teacher's reflections:
4. Outreach activities related to environment taken up by students/teachers/schools:
5. Innovative strategies or material development to teach environment related topics in schools

Year 2017
Main Theme: Use of ICT in Teaching-Learning Process
Sub-theme:

1. Using new technology in classrooms
2. Creating e-materials / e-teaching aids
3. Using ICT in student projects
4. Computer based assessment
5. Social and Cultural aspects of using ICT in teaching learning
6. Issues of equity and equal access within ICT

Year 2016
Main Theme: Encouraging and Supporting students' thinking" in class room learning/ teaching of science

Sub-theme:

1. Handling of "Students' common errors & related doubts".
2. Encouraging involvement of "non-participating students".

3. Using students' out of school experience.
4. Impact of language barrier on science learning, if any.

Year 2015
Main Theme: Collaborative Learning: A Useful Teaching-Learning Method
Sub-theme:

1. Elements of collaborative learning, methodology for implementation and assessment
2. Collaborative Learning Experiences through interactions (Teacher-Teacher, Teacher-Student, Student-Student and Teacher-Parent)
3. Experiences in planning and conducting collaborative learning during scientific investigations (experiments)
4. Experiences in planning and conducting collaborative learning during scientific enquiry in class rooms
5. Assessment of collaborative learning and examples of evidence of learning.

Year 2014
Main Theme: Demonstration of Science Experiments in High Schools
Sub-theme:

1. Inexpensive Science kits for demonstration
2. New experiments for inclusion in the class
3. Practical classroom management techniques
4. Measurement tools as a part of classroom accessories
5. Day to day objects as tools of demonstrating science

Year 2013
Main Theme: Project Based Science Learning
Sub-theme:

1. Inexpensive kits for project works
2. Keeping the relevance and focus of the projects
3. Practical project management techniques
4. Measurement and numerical output of the projects
5. Day to day objects as tools of learning science

Year 2012
Main Theme: Hands-on Science in Schools

Sub-theme:

1. Inexpensive Science kits for demonstration
2. Practical classroom management techniques
3. New experiments for inclusion in the class
4. Measurement tools as a part of class room accessories
5. Day to day objects as tools of learning science

Teachers' Conference 2019
(As part of Science Utsav 2019)
12-01-2019

Time	Description	Speaker/s
9:00 - 9:30 h	Registration and Assembly	
	Plenary Session 09:30 - 1020 h	
9:30 - 9:35 h	Welcome and Introduction	Dr. A. M. Bhagwat
9:35 - 9:40 h	Opening Remarks:	
	Remembering Prof. Chitra Natarajan	Dr. Narendra Deshmukh
9:40 - 10:15 h	Chief Guest	NMMC Representative
	Guest of Honour	Dr. Nicholas Correa
10:15 - 10:20 h	Vote of Thanks	Dr. DAR Babu
Tea Break (10:20 to 10:35 h)		
Session I: to cover sub-themes. (1) Understanding our Learners (2) Learning Environment in the classroom		
Session Chair: Dr. Narendra Deshmukh	**Session co-chair: Rohini Karandikar**	
	Session I: 10:40 - 13:00 h	
10:40 - 11:15 h	Invited talk:	Dr. Narendra Deshmukh
11:20 - 12:00 h	Invited talk:	Prof. Sunita Wadikar
12:00 - 13:00 h	**Teacher's Presentations**	
	Lunch Break (13.00 to 13.40 h)	
Session II: to cover sub-themes. (3) Role of Subject Matter Knowledge in teaching science (4) Teaching Strategies for Science		
Session chair: Dr. Reema Mani	**Session co-chair: Rohini Karandikar**	
Session II: 1340-1630 h		
13:40 - 14:20 h	Invited talk: Dr. Reema Mani	
14:20 - 14:50 h	Teacher's Presentations	
15:00 - 16:00 h	Invited talk: Dr. Meena Sharma	
16:00 - 16:30 h	Feedback and Conclusion	
	Feedback and suggestions	
	Distribution of Participation Certificates	
	Closing remarks and conclusions	
	Vote of Thanks	
	Tea	

Subject and Pedagogical Content Knowledge in Science Teaching

Contents

No	Author	Title	Page No.
1	Concept Note :	Subject and Pedagogical Content Knowledge in Science Teaching	11
2	Alka Gadewal	Seven innovative teaching methods for effective learning of Science in School	14
3	Aniket Farande	Collaborative Learning : Teaching Strategy	16
4	Bhumika Bhowmick	Pedagogy for Science Education	18
5	Usha G	Pedagogy of Teaching Science	21
6	Meena Sharma	Understanding Electricity	24
7	Sunita Wadikar	Subject and Pedagogical Content Knowledge in Science Teaching	25
8	Reema Sanjay Mani	The Role of Subject Matter Knowledge in Teaching Science and the Strategies for Teaching Science	28
9	Late Prof. Chitra Natarajan	Tools For Inquiry Based Science Teaching* *(The article is reproduced here for information only)	30

Concept Note
Subject and Pedagogical Content Knowledge in Science Teaching

Pedagogy is a term that is used in education as a synonym for teaching or a "bag of teaching tricks". It has more to do with understanding the relationship between teaching and learning in ways that foster student's development and growth. Lee Shulman, an American educational psychologist and researcher, noticed that all learners need a teacher who is more than just knowledgeable about their subjects. Learners also need one who can teach their specific subjects clearly and effectively. He called this combination of content and teaching knowledge or the integration of subject expertise and skilled teaching of that particular subject as Pedagogical Content Knowledge (PCK). He further describes PCK as, the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction(Shulman, 1987).

According to Shulman, content knowledge is the teacher's knowledge about the subject matter which includes knowledge of concepts, theories, ideas, organizational framework, and evidence and proof, as well as the practices and approaches that lead to developing such knowledge (Shulman 1986 in Koehler & Mishra, 2009). He defined pedagogical knowledge as the teacher's deep understanding of the processes and practices or method of teaching and learning. Pedagogical knowledge includes: understanding the nature of the learners, having strategies for evaluating the learners, and understanding the cognitive, social and developmental theories of learning and how these apply to learners in classroom.

A) Understanding our Learners: As a teacher, we should understand our learners. Learners are individuals who bring their own needs and experience to the learning environment. An effective teacher appreciates the importance of this (prior) knowledge in creating a successful learning experience. Our learners (students) have different levels of motivation, attitudes, and responses to specific classroom environments and instructional practices. The more thoroughly teachers understand these differences among them, the better the chances of learners in learning what is being taught. Additionally teachers are expected to be aware of learner characteristics such as: level of attainment, age, interests, preferred ways of learning, group dynamics, motivation to learn, educational, social, cultural and linguistic backgrounds, any special educational needs both generally and in relation to specific subjects.

Apart from understanding learners' diversity, teachers have to spend time to determine the extent and nature of learners' prior knowledge and skills. Learners come to the classroom with a variety of pre-existing knowledge, skill-sets, beliefs, and attitudes, which play a role in how they may receive, interpret and organize new information. New learning is constructed on prior knowledge. The more we understand about what our learners already know, the more we can help them to engage and learn well.

It also gives ideas to teacher to craft instructional activities that build off the students' strengths, acknowledge and address their weaknesses, and address their misconceptions. There are several different methods to assess pre-existing knowledge and skills in learners such as; concept based objective tests, concept maps, concept inventories, portfolios, self assessment probes, auditions, etc.

B) Learning Environment in the Classroom: Learning environment can refer to an educational approach, cultural context, or physical setting in which teaching and learning occurs. The learning environment is differs from school to school, classroom to classroom and context to context. The learning environment is broadly classified as: learner-centered, knowledge-centered, assessment-centered, and community-centered. For effective teaching the classroom environment is a teaching resource. Developing a classroom environment conducive (positive) to learning is a process that entails staging the physical space, getting the learners to cooperate, creating a communal environment, and finally maintaining a positive classroom climate and culture (Lynch, 2016). Learning environment also includes: the characteristics of the learners, the goals for teaching and learning, the activities that will best support learning, the assessment strategies that will best measure and drive learning and, the culture that infuses the learning environment. To create a conducive and safe learning environment teachers have to focus on the learners' cohesiveness, involvement, cooperation and equity.

Another important responsibility of the teacher is to develop a learning environment where learners feel motivated to learn within the boundaries and expectations of a safe classroom. When the learners understand that their teacher has well meaning intentions, care about them and have their best interests, learners feel comfortable raising concerns, asking questions or doubts, making mistakes and taking risks in order to learn something new. While it is the teacher's job to facilitate and model proactive and positive expectations, it remains the responsibility of every learner in the classroom to care for and encourage one another.

The role of the teacher and the classroom environment on educational achievement has been an important topic in science educational research, and more recently the peer and home learning environments have been a focus of research. It has been found that learners developed more positive attitudes in classes where the teacher was perceived to be highly supportive, equitable, and where the teacher involved learners in investigations and provided an opportunity to ask questions. Creating an inclusive learning environment for learners is probably the most creative part of teaching.

C) Role of Subject Matter Knowledge in Teaching Science: Mastery of the subject matter will help the teacher to impart knowledge effectively and confidently. It is through the mastery of subject matter that the teachers are able to not only influence the learners' understanding of the subjects they learn, but also design good lesson plans for effective teaching. Teachers' subject matter knowledge is a major element of what is transferred. Subject matter knowledge has a very important role to play because high-quality teaching rests on teachers' understanding of the subjects they are teaching, broadly knowing the structure and sequence of concepts, developing factual knowledge essential to each subject and guiding their learners into the different ways of knowing. It is also well known that when teachers lack subject expertise, there are chances of learners developing misconceptions or alternative conceptions. Teachers often lack opportunities to develop their subject content knowledge in science where new developments take place at an accelerating rate.

D) Teaching Strategies for Science: Research over the past few decades has shown that effective teaching practice is linked to inquiry, reflection, and continuous professional growth. Student engagement and understanding of materials is given more emphasis in today's education over spoon-feeding of facts. Good science teachers are those who teach for deep understanding by using learners' ideas about science to guide lessons, provide experiences to test and challenge those ideas and help learners arrive at a more sophisticated understanding (Wildy and Wallace, 1995). There are certain learner-centered teaching models, such as, the generative learning model, the 5E (Engage, Explore, Explain, Elaborate,

and Evaluate), the interactive model, cooperative learning, concept mapping, POE (Predict-Observe-Explain) approach, group discussion, exploration and problem solving, etc., are beneficial for developing conceptual understanding and students active involvement. Use of creativity, imagination, and innovation, along with planning, practice, decision-making, and evaluation is basic requirement for an effective science instruction. There are many constructivist teaching approaches which are helpful for learners to interact with science in a more organized and structured way. These can include: Hands-on learning, Story-telling, Role-play, Sports-based learning, Word games, Graphic organizers, Use of social media, Virtual science labs, Thinking maps, Context-based learning, Computational thinking, Embodied learning, Project-based learning, Multimedia approach, Science fairs/exhibition, Mobile apps for science, Field trips, Science clubs, etc.

Science teachers, practitioners, researchers and teacher-educators can share their empirical experiences on the broad theme of theme of "Subject and Pedagogical Content Knowledge in Science Teaching" and four sub-themes, namely, Understanding our learners, Learning environments in the classroom, Role of subject matter knowledge in teaching science, and, Teaching strategies for science.

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Seven innovative teaching methods for effective learning of Science in School

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Abstract

The modern civilization is a scientific civilization. In this age the modern society is completely drawn into the scientific environment. Today science has become an integral part of our life & living. Now we cannot think of a world without science. Imparting science education is the field concerned with sharing science content and process to children's in school. Therefore a science teaching method comprises the principles and innovative methods used by teachers to enable student learning. The best seven innovative methods can substitute the typical teaching techniques to achieve the goal.

1) **Hands on learning**: This is the best teaching method invented so far that involves the active participation of students to experience scientific concepts than to just have an audience view. Schools are promoting the use of low cost apparatus in classrooms to helps students to have hands on learning experience. It can be a string telephone to teach about sound and communication, matchstick mecanno to teach 3D structures, notched pencil to teach rotation motion or anything similar.

2) **Words parts**: This teaching strategy is followed by teachers to educate the basics of science to elementary students. While introducing new scientific terms, they can reinforce the structure of words. Students are asked to identify and understand prefix, suffix, and base word, and to relate their meanings. For example, metamorphosis — meta (large), morph (change), osis (process); photosynthesis — photo (light), synth (make), isis (process).

3) **Visual clues**: Using visual clues easily supplements auditory information and students can easily connect better with ideas. The multi-sensory experiences improve their understanding and memorization. This includes drawings, diagrams, and pictures to assist theory and setting up examples to show its application side.

4) **Virtual science labs**: There are many virtual science labs available online for free and therefore, this approach almost gives hands on experience of learning the subject without much expense. Detailed diagrams, illustrations or close up pictures allow students to virtually get inside a plant or animal part without actually doing it. Dissections in biology can be studied thoughtfully with a virtual hands-on sensation without the problem of odour and similarly, experiment a chemical reaction without burns.

5) **Science movies**: Teachers take initiatives to take them for science movies in theatres or in school halls that clearly showcase the application side of scientific concepts. More than just entertaining them, many science movies captivate their attention and illustrate diverse science concepts in the real world. Science and nature-focused documentaries is one of the best ways to introduce science to kids than spoon feeding them with text book content.

6) **Mobile apps for Science**: A number of mobile apps are available online for elementary, middle school and high school students as well as for those undergoing advanced studies. Today's kids are tech savvies and they love to learn science using their gadgets. The advanced mobile apps built

with innovative features in fact turn students into scientists. This lets them hold science in their hands and explore it with just a few taps. The popular apps in the category include Human Body, Cozmic Zoom, Earth Primer, Video Science, Science360, NASA GLOBE Observer and a lot more.

7) **Science at home:** Like scientists say, science starts from home. Encourage your students to discover science at home from elementary classes itself. Ask them to find out a specific science concept application at home as assignments and let them discover science on the go.There are fun science activities at home that involve parents and kids such as measuring Earth's circumference with a shadow, creating under water fireworks with chemistry, building a balloon powered toy car and a lot more.

Collaborative Learning : Teaching Strategy

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Abstract

Science has played a pivotal role in understanding various phenomena associated with nature. A proper trajectory always helps an individual to circumvent the problem he comes across in his day to day life. Nevertheless the solution is often ameliorated and amended and the answer to a particular problem evolves with the resources available around us. This makes it easy for a new person to refer to existing solutions and hypothesise new laws related to science. All these methods help a student to master a given concept which is the main aim of any pedagological technique.

Pedagogy and learning

Pedagogy refers to the theory and practice of education and how it influences the growth of a learner. It deals with the study of how knowledge and skills are exchanged in an educational context and considers the interactions that take place during the learning process.

Every different strategy adopted by a teacher to attain various maxims of teaching play a formidable role in advocating a constructive approach towards the process of learning. One of the most effective teaching strategy which can be employed by a teacher is collaborative learning.

Collaborative learning

In this method the students are divided in groups and a task is assigned to each group. The students need to understand analyse and interpret given problem and express their views on how they can find a solution to a given problem. For example in order to teach the neutralisation reaction the teacher can use the concept of titration. The teacher can divide the students in different groups and can encourage the students to find out various acids and bases they come across in nature. Further with the help of titration the teacher can demonstrate the neutralisation reaction and encourage the students to carry out the titration of various acids and bases using suitable indicator. During the demonstration the teacher can make use of syringes and glasses which are easily available. Further a concept of indicator using turmeric and a base will help students to discern between acidic and basic conditions. After teaching the concept of acids and bases it becomes easy to explain the neutralisation reaction. Since the understanding of scientific knowledge starts with general things and moves towards specific things it becomes easy for a student to grasp the knowledge to his maximum potential. Moreover the students are exposed to various acids and bases occurring in nature. This helps the students to explore the world around them with a scientific perspective and discourages the idea of rote learning.

Merits of collaborative learning

Collaborative learning teams are said to attain higher level thinking and preserve information for longer times than students working individually. This is because groups tend to learn through discussion, clarification of ideas and evaluation of others ideas. The idea of collaborative learning finds

its root in Vygotsky's idea of 'zone of proximal development'. It helps to better performance of a student if aided properly by peers and adults. Effective collaborative learning involves the establishment of group goals as well as individual accountability. This not only keeps the group on task but also establishes an unambiguous purpose. Moreover the students are at an advantage as the goals and objectives are already defined at the beginning of assignment. Thus collaborative learning proves to be an effective strategy in imparting scientific knowledge to the students.

Pedagogy for Science Education

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Abstract

All subjects are equally important. Each one has its own aura, implications and significance. The beauty of science is its omnipresence, open-endedness, its rich and varied prospects. The subject itself is highly versatile and self-explanatory only waiting to be observed keenly, explored vividly and experienced within. Science is as much as in book as it is all around us. It showcases its specimens everywhere. 'Seeing is believing' can be best applied while imparting the concepts in science. Most of the concepts can be demonstrated with the help of simple experiments such as properties of light, air, water, soil, acids, bases etc. The natural phenomenon can be explained through pictures, videos and models etc.

New concept building develops upon a firm foundation of known ideas. The connection between the known and the unknown forms very well in case of general sciences especially at the primary level. The students mostly learn about things and common phenomenon that are happening around themselves, thus it might be a reason for calling science as environmental science at the primary level. It helps to make them aware of the surroundings.

The teaching learning process is a multidimensional one involving the teacher, the taught, the content and the learning environment. If the content is considered as a seed then a student is the soil which has to be made as fertile as it can be before sowing the seed. The teacher feels in as a farmer tilling, ploughing and weeding the soil for sowing. Readying the child to learn is equally important as teaching the concepts.

For the concepts to reach, stay and set in the student's mind, it has to go through a series of steps in a chronological order. It might be diagrammatically shown as:

Generation of Interest à Set induction à Explanation of the concept à Analysis of the concept learnt à Reinforcement of the concept àAssessing the quantum of success achieved in imparting the concept.

The concept 'Properties of Air' can be taught following these steps:

- **Generation of Interest**à Students will be given a balloon each and will be asked to blow it. They will be asked to let the air out of it then. The students will be encouraged to share their observations.
- **Set induction**àThe keywords such as air and pressure will be taken from the class discussion. The properties of air will be then introduced.
- **Explanation of the concept**àThe different properties of air will be explained with other simple experiments along with a mind map drawn stepwise.

- **Reinforcement of the concept**à Reinforcement can be done with the help of mind map drawn on the board. Creative ideas like mnemonics, poems etc. also make it easy and effortless.
- **Assessing the quantum of success achieved in imparting the concept** àIt can be done by asking the students to solve a worksheet having open-ended questions and experiments. They can also be asked to cite more examples of different properties of air.

Every class is a heterogeneous mixture of different kinds of learners. While planning for the lesson different learning styles have to be kept in the mind, for example: Demonstration for the visual learners, learning by doing for the kinesthetic learners and poems and videos for the auditory and visual learners. Last but not least, every topic should impart a value in a discrete and pronounced way. It goes a long way to raise the social quotient of the students, which in today's time is the need of the hour.

The properties of air will be taken for demonstration

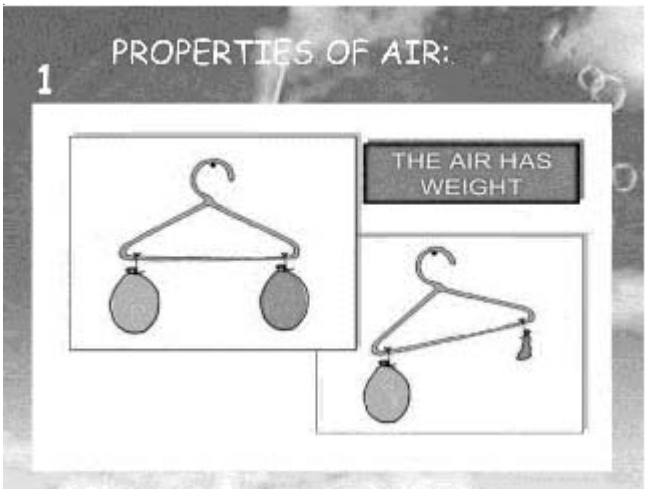
- **Air exerts pressure**

The teacher will blow a balloon and let the air out of it. She will ask the teachers about their observation regarding the same. After the interaction and discussion, the teacher will explain the reason behind activity thereby explaining the topic 'air exerts pressure'. The teacher will further give more examples of implication of this property of air.

- **Air occupies space (Balloon in the bottle)**

The teacher will show a blown balloon and a plastic bottle. She will try to put the balloon in the bottle. She will ask the fellow students to give it a try. After many attempts the teacher will show another bottle with a balloon in it. The teacher will show how to put the balloon in the bottle. While performing the activity the teacher will explain the topic ‘air occupies space’. The teacher will further give more examples of implication of this property of air.

- Air has weight



The teacher will show two balloons hanging on a hanger. She will ask the fellow students to observe carefully. She will then burst one balloon and will ask to observe it again. After discussing the observations the teacher will explain the topic ‘air has weight’.

Pedagogy of Teaching Science

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Abstract

Pedagogy refers more broadly to the theory and practice of education, and how this influences the growth of learners. Pedagogy, taken as an academic discipline, is the study of how knowledge and skills are exchanged in an educational context, and it considers the interactions that take place during learning.

What is science?

Human beings are curious by nature. They have highly developed minds which help them to observe precisely, correlate observations and predict future. This ability has helped human beings to adjust with nature. They explore, understand and change the physical world according to their own needs and requirement. The process of observing, exploring and using the physical world is nothing but science.

Science as a process:

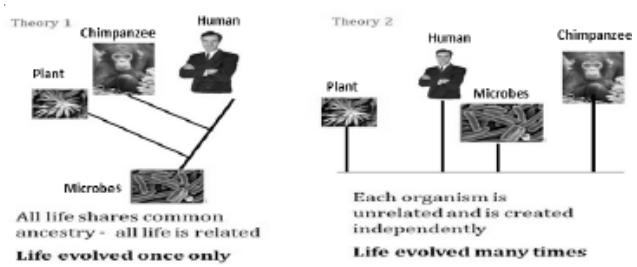
Process as a word is extensively used as teaching process, learning process, examining process etc. In science, the way of gathering information, thinking, measuring, solving a problem or in other words the way of learning science is called process of science.

The pedagogies for a great science lesson are as follows:

Discussion: Students should focus on why a claim should be believed and not what shouldn't be believed.

Example: The process of evolution can be visualized through discussion. Sometimes students struggle to understand how mutation could possibly bring about variations and evolution.

The students are instructed to write down the percentage of genetic material that they share with chimpanzee, microbe and plant. This will then lead to understanding about DNA being the universal genetic code, therefore evidence for evolution by presenting the following pictures.



Literacy in science: Students need to make a sense of variety of words both scientific and non-scientific. It is worth pointing out that literacy in science is different to "Scientific literacy" which refers to understanding the process of science.

Example: For the understanding of Atomic structure the following passage is given to students and questionnaire is given.

Hin Spfli in Science

Hin Spfli was a proton. Alken he goes on a current with Ghen. Spfli and Ghen conducted. Fect in the sild they meet more protons. All the lops dund and then charged.

Questions (to be answered in complete sentences)

What was Hin Spfli?
Where did Spfli and Ghen go?
What did Spfli and Ghen do?
Who did they meet in the sild?
What did the lops do after dund?

So a good literacy is important to students for science education.

Practical work in Science: A demonstration may deliver a much clearer understanding of a scientific concept. Similarly an inquiry based approach could be a great opportunity to motivate students or to encourage them to ask questions.

Example: To understand about the concept of friction the following experiment could be demonstrated. Students are asked to watch a practical lesson on friction that make them think and motivate to investigate how various surfaces had different amounts of friction e.g. wood, carpet and polystyrene. A dictionary was placed on the end of a wooden ramp. The ramp was lifted until the book started to slide. Students measured the height at which sliding occurred and repeated the experiment with different surfaces.

Using drama to teach science: This process will engage and motivate students. Help model abstract ideas to create meaning in students.

Example: To understand the cell structure, students are given a key word like nucleus, cell membrane, mitochondria etc., on a card and have to act it out in front of class as a mime. Other students guess what the word is.

In addition, the most effective pedagogy skill which could be implemented for teaching biology is **Mnemonics.** Mnemonics are fun tools or memory aids you can use to remember the word sequence. Figures, events, face and facts can be mastered and recalled by using memory aids. In fact, using mnemonics is effective compared to other conventional means such as repetition and rote learning.

The advantages of using mnemonics:

1. Improvement in Memory Mnemonics is a powerful tool that can help you improve your memory. While ordinary memorization can be monotonous, using memorization techniques can be an entertaining method to retain valuable information.

2. Helps Children with Dyslexia

Dyslexia simply means reading difficulty or inability to read fluently, despite adequate opportunity and intelligence. However, using mnemonics can help improve reading ability in children with dyslexia.

3. Enhances Imagination

Imagination is important in order to create strong mnemonics. Our information will help us to create effective learning aids to improve our memory. When we strongly visualize and imagine a short phrase, it becomes easy to recall the information later.

4. Retrieves Important Information

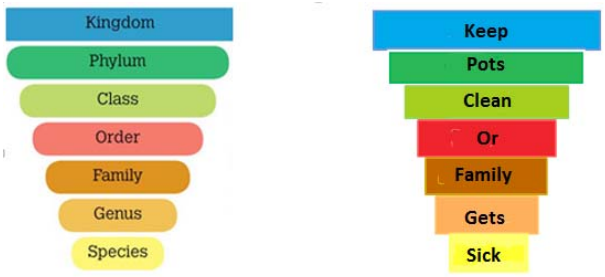
When we try to remember something, the brain activates nerve cells used to store the information. By using mnemonics, it becomes easy to keep healthy function of the blood cells, improving your memory

To start with an example of **Mnemonic**:

Taxonomic hierarchy is the process of arranging various groups, class and other categories into successive levels of the biological classification in a sequence either in a decreasing or increasing order from kingdom to species and vice versa. Each of this level or hierarchy is called as the taxonomic category or rank. In this system of classification, kingdom is always ranked high followed by division, class, order, family, genus, and species which is always ranked the lowest in the hierarchy.

To remember the order of taxa in biology we have the following mnemonic:

Keep pots clean or family gets sick, which is represented as below:



This skill can be adopted for memorizing various concepts or labeling of a diagram at different grades for teaching science. Thus the pedagogy adapted by teachers shape their actions, judgments and other teaching strategies by taking into consideration of learners' understanding, the background and interests of individual students.

Understanding Electricity

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Abstract

The session on understanding electricity would comprise of demonstration -cum- hands- on experimentation. The very basics of electricity; its components, circuitary, construction, and applications would be discussed and demonstrated. The participants would then be given hands-On experience for building and boosting comfort level in them. With improved understanding, through this simplified approach, the participants can disseminate the same with great ease, while addressing their pupils.

Subject and Pedagogical Content Knowledge in Science Teaching

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Abstract

The UNESCO Education for All (EFA) Global Monitoring Report 2005 highlights the central role of teachers in any education system, emphasizing that the quality of education is directly linked to how well teachers are prepared for teaching. In today's world, teachers need to be equipped not only with subject-specific expertise and effective teaching methodologies, but with the capacity to assist students to meet the demands of the emerging knowledge-based society.

- Pedagogy is a systematic study about science of teaching and learning. It is about how knowledge be organised effectively and used in order to implement the Curriculum.
- Whereas, Pedagogical Content Knowledge is the integration of subject expertise and skilled teaching of a particular subject. This concept was first developed by Lee Shulman in 1986.

A) Understanding our Learners:
'If a child can't learn the way we teach, maybe we should teach the way they learn'.

- Ignacio Estrad

Our education system is totally in a state of flux today. There is confusion in the minds of the students over the board of affiliation, teaching, learning pedagogy as well as the career options to be selected. Moreover, even though we are already in the 21st century, our education system and its dissemination is still lingering in the 20th century transactions.

There is a dramatic change in the present day learner profile too.

Today's learner is having tremendous exposure to the information & communication technology resulting in changing their mental configuration altogether. We observe that present age students are fast learners, swift thinkers and quick decision makers, therefore, there is a need to align our education system to the needs of more emancipated and empowered learner belonging to the new age era.

Learners generally have different learning styles like Visual, Aural, Read-Write or Kinaesthetic (VARK) and apart from this we have to also consider the Multiple Intelligence theory given by the great Psychologist Gardner. Students possess different types of Intelligences and as teachers we need to cater to them. Lastly, the skills required in the 21st century should cater to the needs of the global citizens by training them to become lifelong learners which will help them in keeping pace with the exponential growth of the ICT. So the realisation has dawned upon, that the present day learner is altogether a different entity and that there is an urgent need to bring in transformation in our pedagogy & the entire education system.

B) Learning Environment in the Classroom:
In the last decade of 20th century onwards educational practices started getting influenced by "constructivism" which believed in 'Knowledge Creation' in contrast to the dominance of behaviourism

in the major part of the 20th century wherein, teaching models predominantly believed in "information transfer".

In the early years of 21st century, new pedagogical practices changed from the traditional practices of lecture mode to interaction mode making social interaction as a necessity for learning to happen. A number of new technologies and Collaborative, Co-operative techniques of teaching are being used to enhance the social interactions as well as involvement of the learners actively in all the educational endeavours.

Some of the very important areas which need to be revisited and changed are moving from 'theory' to 'practice' and changing the overall pedagogies and techniques to be used for teaching, learning and evaluation as well.

Most of the Educational Psychology theories of learning have proved that 'Learning by Doing' is the best way of learning effectively. Student Engagement is the buzz-word today and the teaching pedagogies adopted in classrooms play a very important role in enhancing the level of student engagement.

Knowing this we realise that Student engagement plays a crucial role in the entire teaching, learning process. When students remain engaged on the task they get interested and remain motivated and enthusiastic. Also the retention of the content analysed and learnt is much longer. The new version of modified Blooms taxonomy too emphasises on knowledge creation which can be achieved through activity based learning and Constructivism.

'Constructive alignment' is the process that we usually follow when we build up an outcome based learning syllabus. It is a term coined by Professor John Biggs in 1999, which refers to the process to create a learning environment that supports the learning activities appropriate to achieving the desired learning outcomes. The word 'constructive' refers to what the learner does to construct meaning through relevant learning activities. The 'alignment' aspect refers to what the teacher does. The key to the alignment is that the components in the teaching system, especially the teaching methods used and the assessment tasks are aligned to the learning activities assumed in the intended outcomes. Over last few decades, educators and researchers have exhibited interest in the concept of engagement as a means to enhance students' motivation and involvement in education related experiences, to remove student aversion and to increase student achievement levels.

ICT integration can be sought through Curriculum, Resources and Skills for enhancing the Student Engagement. Bill Gates has rightly remarked,

"We at Microsoft strongly believe that the single most important use of ICT is to improve education"

Meeting the 21st Century Assessment Challenge:

We observe that there exists cognitive diversity without the teaching diversity & Learning diversity without the assessment diversity.

The most important lacuna which is observed in the education system and needs to be addressed is that of the redundant assessment procedures. No matter what amounts of innovations are implemented

in the classroom, the teaching learning process in the classroom is bound to remain skewed without the improvisation of the assessment procedures adopted.

Our education system therefore, requires a balance of technology-enhanced, formative and summative, synchronized as well as asynchronized assessments that will cater to the individual differences and measure student mastery of 21st century skills.

Role of the teacher for sustainable learning :

Teacher as a facilitator needs to keep upgrading constantly by being a life long learner which can be made possible by participating in various Online Educational Resources.

They require familiarity with new forms of information and communication technology and need to have the ability to use that technology to enhance the quality of teaching, learning and assessment.

It may be said that implementing 20th century pedagogy in the 21st century classrooms would only prepare the learners for a world that does not exist at all. So there is a need to bring about a paradigm shift in the teaching, learning & evaluation process. The focus needs to be shifted not only from the ‘teacher to learner’ but from ‘teaching to learning’.

More importantly, what actually matters is what is learned rather than what is taught. The teacher in this futuristic approach as opposed to being the repository of knowledge must now be a facilitator of learning.

The Role of Subject Matter Knowledge in Teaching Science and the Strategies for Teaching Science

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Abstract

A doctor needs to know the medical subjects, a mathematician must know mathematics, a writer must have good knowledge of language and literature. And a teacher who teaches all of them must know her subject. Subject matter knowledge is the foundation of good professional ability.

Lack of subject matter knowledge has implications for the teacher whose actions will reflect the problems. Proficiency in your subject is important to guide others through the content. To teach the subject matter, it may be argued that more than a sound knowledge is required in science. Only a teacher who knows the subject will be able to make the subject matter easy and accessible to the students. Schulman (1991) explained that a good teacher should be able to scaffold what her students own understanding of the subject and what they should gain.

A teacher of science must be able to take cognisance of students' existing knowledge, any misconceptions and also provide new content that challenges what they already know. What happens when there is a knowledge deficit in the teaching adult? Firstly, teachers who are lacking in science content knowledge will be lacking confidence (Symington and Hayes, 1989). They will also not be able to create 'meaningful learning'. The teacher must have sound knowledge so that she can create meaningful experiences for the students. Knowledge deficit also does not allow the teacher to ask questions, select tasks, evaluate their pupils' understandings and make curriculum choices (Ball & Anderson, 1989). Teachers need good subject knowledge to be able to "frame accurate and high quality explanations, and they need it to diagnose accurately misconceptions" (Bennett & Carre, 1991).

Lack of subject knowledge also affects the confidence of the teacher negatively – a positive attitude affects classroom practice. Effective teaching also requires students to engage with the subject, especially in understanding the complex inter-disciplinary subject like science. Teachers who have subject matter knowledge make connectionist relationships between concepts in science and are found to be more effective than teachers who teach via transmission method (Askew, Brown, Rhides, Johnson and William, 1997).

Although the emphasis here is on subject matter knowledge, there are other kinds of knowledge that a teacher must have (see Schulman, 1987):

1. general pedagogical knowledge

2. curriculum knowledge

3. pedagogical content knowledge – how to teach the subject matter

4. knowledge of learners and their characteristics

5. knowledge of educational contexts

6. knowledge of educational goals, values and purposes, including the history and philosophy of education (here, science also).

The pedagogical content knowledge helps a teacher to create strategies for teaching science. It is simply the ability to make the subject more accessible to students by various teaching methods, using powerful analogies and metaphors, enabling hands-on exploration, allowing inquiry and encouraging inquiry, providing students with the rich history of science to help them acquire the knowledge and practices of the scientific community, etc. Other knowledge specified above are tied within the strategies that are selected for teaching because the epistemic questions of the pedagogical practices are rooted in the knowledge of curriculum, policies, contexts, needs and goals.

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Tools For Inquiry Based Science Teaching

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(The article is reproduced here for information only)

1. Introduction

Young children love play and like to make things. They are ost focused when working with their hands. The position paper on the teaching of science (NCF, 2005) was supported by a large body of research on science education. It recommends that teaching should involve students in hands-on activities, and should be inquiry-based. As an idea, this is widely accepted by teachers and teacher educators. Still, teaching in all schools tends to be mostly dominated by the teacher talking and using the blackboard. If classrooms must become activity places for children while learning science, the textbooks must require teachers to start with things that are directly related to the child's experience. The teacher needs to start with specific experiences and then progress to the general.

Some 'topics' may need to be reordered in the textbooks to reflect the hands-on approach. For example the idea of electric charge is introduced long before asking students to work with electric currents. In an hands-on approach, students will first make electrical circuits and study many aspects of electric current, based on their every day experiences. Only after they are comfortable working with current, they will be introduced to the abstract ideas of charge,
and current as charges in motion.

2. What is scientific inquiry?

Young children are naturally curious. They ask questions about everything around them. Scientific inquiry also begins with curiosity about the world in which we live, and posing questions. But scientific inquiry is more than just asking questions. After raising the question, students need to come up with hypotheses (or knowledge based guesses) that can be tested. Experiments must be planned for testing which guesses are correct, and students must conduct experiments collecting data. The data must be recorded and analysed, through suitable calculations and it must be shown how they support a guess or not. The findings must be presented to others

Science inquiry also means investigating ideas, solving problems, arriving at valid conclusions and making arguments based on evidence. It is very important while doing science to recognise that scientific explanations change when new or different evidences become available. Science activity may also start with making observations, then posing questions, reading books to find out information that is already known, and then planning observations by conducting experiments, and so on. Scientific inquiry requires students to use"critical and logical thinking to consider different explanations, evaluate them, and choose the correct one.

3. How can teaching be inquiry-based?

It is natural for students to be curious and ask questions. The process of science is systematic inquiry. NCF 2005 recommends hands-on activities and inquiry based teaching. Hence teachers, must

create a classroom in which their students are developing inquiry skills. What are these skills? The skills include asking good questions – not only “what” questions, but also “why”, “how” and other complex questions. They need planning skills – to plan an activity or experiment that will help them find answers to their questions. They need skills to conduct the activity, make important observations, record their observations, make suitable calculations, interpret the results and evaluate whether they answer the questions that they had. Students also need communication skills to present their questions, activities and results to others.

In inquiry-based teaching, children are actively constructing their understanding about science, scientific concepts and phenomena, while they are learning skills to carry out their own explorations. Hence the inquiry based teaching is one of the contructivist approaches to teaching-learning. We say that students are involved in inquiry-based learning when they are developing understanding of a science topic through finding out answers to questions. They develop explanations based on evidence they collect, modify their explanations based on further applications, communicate and justify their conclusions.

Table 1 gives a list of teaching-learning aspects that inquiry based teaching requires. The left column gives what needs to be reduced, and the right column list what must be focused on more often. The question that arises in many teachers' minds is, “Should I teach all science topics by the inquiry-based method?” The answer to this question, in general, is “No.” Some topics in the science syllabus are more suitable for inquiry-based teaching than others. Some activities may be more dangerous for students to work on their own. It also depends on the nature of the topic or question raised, the resources available to students, the time available, and how well the students are able to work without guidance or with very little guidance from the teacher. Besides, the teacher's own confidence in the content of the topic and skills for doing the activities are very important. Teachers must do as many topics as they can through inquiry-based teaching. They also need to build their own content knowledge and inquiry skills to do inquiry-based teaching in more and more topics each year.

Several tools can be used by teachers for inquiry based teaching. Teachers can provide situations in the classroom for students to develop collaborative and cooperative learning skills. They must always respond to students' questions by asking questions that make students think and get closer to finding their own answers. Students can be asked to make concept maps and brainstorm in groups. While working in groups, each group can send a member as an envoy to another group to exchange ideas between groups. Groups can make and put up posters and other products, and organise a gallery walk of all groups around the“exhibition. Assessment must also change to match the needs of inquiry-based teachinglearning as indicated in Table 1.

Table 1: Inquiry based teaching (Dawson, Koul, Natarajan and Chunawala, 2012)

Inquiry-based teaching requires LESS emphasis on:	**Inquiry-based teaching requires MORE emphasis on:**
science being interesting for some students	science being interesting for all students
covering many science topics	studying a few fundamental concepts
theoretical, abstract topics	content that is meaningful to the student's experience and interest
presenting science by talk, text and	guiding students in reading and writing text,
demonstration asking for recitation of acquired knowledge	in activities and extended student inquiry providing opportunities for discussion among students
individuals completing routine assignments	groups working cooperatively to investigate problems or issues
activities that demonstrate and verify science content	open-ended activities that investigate relevant science questions
memorising the name and definitions of scientific terms and facts	learning broader concepts that can be applied in new situations
learning science mainly from textbooks provided to students	learning science actively by seeking understanding from multiple sources of information, including books, Internet, media reports, discussion and hands-on investigations
assessing what it easily measures	assessing learning outcomes measured that
	are most valued
assessing recall of scientific terms and facts	assessing understanding and its application to new situations, and skills of investigation, data analysis and communication
end-of-topic multiple choice tests for grading and reporting	ongoing assessment of work and the provision of feedback that assists learning

4. The 5E Model

A number of models have been developed to help teachers plan and structure inquiry-based teaching-learning classrooms. The 5E model is used by many teachers in the US and Australia. It was developed by a group of science educators from the US, including Rodger Bybee, Paul Kerbis and Susan Loucks-Horsley. The model has are five distinct but interconnected steps as shown in Figure 1."

Source: http://journeyintech.blogspot.in/2011/01/making-science-relevant-using-5es.html What each of these steps mean is given below with a description of the step, the purpose of each step, what activities are involved in each step, and and example of the step in learning about water.

4a, E1 - Engage

The teacher gets the students interested in the topic by using a variety of ways. The context ismportant as connecting to students' experiences will affect how students understand the science concepts that will be introduced. The teacher also wants to know students' existing ideas and possible misconceptions.

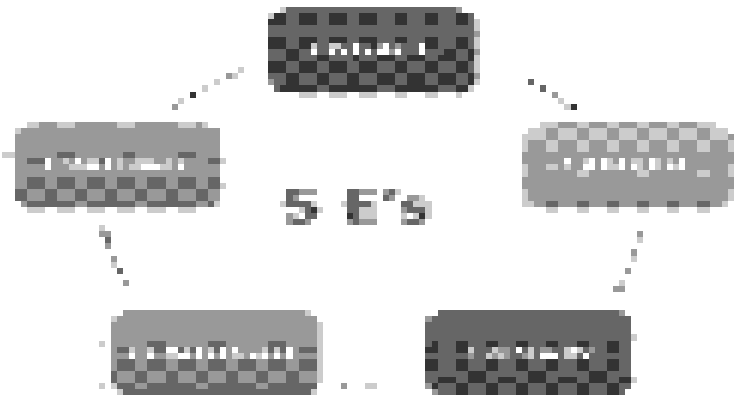

Figure 1: The 5E Model for inquiry-based teaching-learning.

The purpose of engaging students:

- Create interest in students and stimulate their curiosity.
- Set learning within a meaningful context.
- Raise questions for inquiry.
- Find out students' ideas and beliefs, and compare students' ideas.

The following activities can used in this step:

- Set the context, and establish relevance.
- Provide experiences to create interest and raise questions.
- Use open questions, individual student writing and drawing, etc., to find out students' existing ideas – a form of diagnostic assessment.

Example: Start with question - How is water different from other liquids? What physical properties can you observe? Design an activity with drops of water and another liquid, on different surfaces. Use a hand lens, observe, make a table and enter data. Describe the results.“How are drops of oil and water different?

4b. E2 - Explore

In this step students carry out hands-on activities to get a common set of concrete experiences. The science concepts or skills can be connected to these common experiences of all students. While students are doing activities, teachers encourage students to talk about what they are planning and doing, using their own language to make connections and discuss ideas.

The purpose of this step is to:

- Provide experience of the phenomenon or concept.
- Find out students' questions and for students to test their ideas.
- Investigate and solve problems.

This step involves the following activities:

- Open investigations to experience the phenomenon, collect evidence through observation and measurement, test ideas and try to answer the questions.
- Investigation of text-based materials (newspaper articles) with considerations of critical lit eracy, making judgements about reliability of sources or the scientific claims made.

Example: What makes water a special chemical? Read in books and internet and gather information about the water molecule.

4c. E3 - Explain

After getting a common set of experiences, students explain their observations and findings. This gives students a chance to develop a better understanding of the science concepts. Students can get help from the teacher, other students or books, the internet, etc. It is at this point that teacher introduces science terms and scientific language so that students can more clearly and correctly talk about the science concepts.

The purpose of this step:

- Introduce tools that can be used to talk about the observations and data, and construct explana tions of the phenomenon.
- Construct explanations and justify them in terms of observations.
- Compare the explanations of different students or groups.
- Consider current scientific explanations.

This step involves the following activities:

- Making available to students the concepts and terms to help them in explaining phenomena – either by giving reading materials or by teacher's explanation.
- Small group discussion to generate explanations, compare ideas and explanations.
- Individual writing, drawing and mapping to clarify ideas and explanations.“
- Formative as sessment to provide feedback to teacher and students about development of investigation skills and conceptual understanding.
- Small groups design a communication product (poster, drama, etc.) with attention to form of argumentation, audience, using different modes for representing science ideas. Example: Con duct activities on cohesion of water molecules. Predict results of each activity, and explain the observations.

4d. E4 - Elaboration

This is the application step, because students apply what they have learned through the last three steps to new situations. Trying to apply their learning will also help students refine their ideas. During this step students will use the scientific terms and language in their discussion.

The purpose of this step:

- Use and apply concepts and explanations in new contexts to test their general applicability.
- Extend explanations and understanding using different modes like writing, diagrams, and graphs, and integrate their learning from different subjects like mathematics.

This step involves the following activities:

- Investigations planned by students, and exercises, problems or design tasks where they can apply, clarify, and extend new conceptual understanding and skills.
- Further reading, individual and group writing may be used to introduce additional concepts and clarify meanings through writing.
- Making a poster or drama or some product for exhibiting through which students present their ideas using different representational modes.

Example: Apply understanding properties of water to everyday situations.

4e. E5 - Evaluation

Assessment is an important part of any learning process. Both students and the teacher need to know how much has been learnt and understood.
The purpose of this step:

- Provide situations for students to review their own learning and new understanding and skills.
- Provide evidence for change in students' understanding, beliefs and skills. This step involves the following activities:
- Discussion of open questions, responses to open questions from students in writing and diagrams; teacher may use questions similar to those used in the first step to find out the extent to which students know the related concepts and phenomena.“• Discussing the difference between the explanations given in the first and last steps to help students become more aware of their own learning.

Example: Discussion of how students arrived at their understanding about water, and what more questions they can ask.

5. Conclusion

Each step in the 5E model serves an important purpose in inquiry-based teaching-learning. Yet, each step can also be independently conducted with the students to benefit them. Teachers are very good at asking questions. But they normally ask only close ended questions that have one known correct answer. Teachers rarely ask open-ended questions to which students can give different answers. The answers will give the teacher an idea of how students are thinking. It is more important for teachers to understand students' thinking on any topic than to simply get correct answers. Teachers can use the discussion in class following the multiple answers to arrive at an understanding of the concepts involved. This needs practice for the teachers, who needs to have content and confidence, which they must develop.

The investigation activities involving predict, observe and explain should also be carried out with students as often as possible. Explanations should as far as possible be based on what can be inferred from students' observations. This is at the heart of doing science and gives students an idea of the nature of scientific investigations.

An important aspect of all teaching-learning processes is assessment. Evaluation and assessment must focus on student learning, rather than on labelling students as good, average and bad performers. It must be continuous and include content application as well as procedural skills, cooperative and collaborative learning skills, and the ability of students to learn. It must help students assess themselves. For this the teacher must plan all the assessment conditions before conducting the activities and also share this with the students. Evaluation is primarily for teachers to get feedback on what they can change in their planning and conducting of inquiry-based teaching so that their students learn better.

An inquiry-based teaching is also an inquiry of the teacher on the teaching-learning process in science education. The teacher is both a learner and a researcher. Best wishes to all teachers who want to go on this path.

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