BES-141
Pedagogy of Science

Indira Gandhi
National Open University
School of Education

Block

1

UNDERSTANDING SCIENCE

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COURSE: BES-141 Pedagogy of Science

COURSE INTRODUCTION

BES-141: Pedagogy of Science is one of the pedagogical courses being offered in B.Ed. Programme. School of Education has adopted content-cum-pedagogy approach in all the pedagogy courses, thus this course discusses not only the pedagogical aspects of teaching-learning of Science but also some selected content areas from secondary school curriculum, where a secondary school science teacher may need some inputs for smooth transaction of the content.

Major objectives of the course are to help student teachers in:

- understanding the nature of science and its place in curriculum,
- appreciating the importance of development of scientific temper among learners,
- identifying appropriate approach for teaching-learning of science,
- integrating suitable learning resources to facilitate learning in science,
- constructing appropriate assessment tool for assessing learner's progress in science, and
- revisiting few important concepts of science and integrate them thematically.

The Course is divided into Four Blocks.

Block 1: Understanding Science is dealing with issues related to Perspectives and Nature of Science, science as a process of inquiry and value development through science. It also discusses about aims and objectives of science teaching-learning at secondary and senior secondary level, developing learning objectives and shift in pedagogic approach from behaviourism to constructivism. Block will facilitate you in developing scientific attitude and scientific temper, nurturing natural curiosity, aesthetic sense and curiosity and scientific process skills among your learners. It also gives you a brief about historical development of science education in India and present status of science education in India.

Block 2: Teaching-learning of Science is focusing on facilitating teaching-learning process in classroom. It discusses about learning objectives, identifying skills to be developed, content planning and integration in 5-E model. It discusses about inquiry approach, problem solving approach, cooperative learning approach, experiential learning approach, concept mapping as an approach for planning and transaction and about adopting critical pedagogy in science teaching-learning. Various methods in Science teaching-learning like-Teacher-centric methods, Learner-centric methods and Cooperative Learning methods are discussed in the block along with strategies for practicing inclusion in Science classroom and curriculum transaction. Block also discusses about identifying appropriate learning resources. It will also facilitate you in assessing various process skills, identifying and framing assessment indicators in science, using various tools and techniques for assessment of scholastic and co-scholastic domains.

In **Block 3: Content Based Methodology-1** and **Block 4: Content Based Methodology-II,** selected Content from Secondary level curriculum of Science has been taken under each theme and essential aspects of teaching-learning process (i.e. planning, transaction and assessment strategies) have been discussed .

Block 3 is dealing with various concepts under the themes food, material, the living world and how things work. Similarly, Block 4 deals with concepts under the themes like moving things, people and Idea, natural phenomena and natural resources. It is expected that these discussion will help you in planning and adopting appropriate teaching-learning strategy while dealing with similar content.

BLOCK 1 UNDERSTANDING SCIENCE

Introduction to the Block

Block-1 of the course is developed for providing you an understanding of various aspects of science in order to understand nature of Science. This block focuses on meaning and nature of Science. Block will also discuss about aims and objectives and also about process skill, which are to be developed through science teaching-learning. This block has 4 units.

Unit 1: Science: Perspectives and Nature will discuss in detail about meaning and nature of Science. Common myths related to nature of Science will also be discussed so that you can facilitate learners in resolving these myths in order to understand true nature of Science. Unit will also explain the process of scientific inquiry and deliberate on place of Science in society. Unit will propose that Science has its own values system, which is to be developed through teaching-learning of Science.

Unit 2:Aims and Objectives of Science Teaching-Learning will facilitate you in understanding the aims and objectives of science teaching. The Unit will also help you in formulating learning objectives according to Anderson and Krathwohl's taxonomy. Discussion on shift in pedagogical approach from behaviorism to constructivism will help you in understanding changing nature of teaching-learning of Science.

Unit 3:Process Skills in Science discusses on developing these scientific skills of learners so that they can construct their own understanding of science by using inquiry. Unit will discuss how learners can develop scientific attitude and scientific temper while learning science. You have to facilitate learners to develop aesthetic sense while learning science. Unit also discusses the interdependence of all three aspects i.e. science is a body of knowledge, a way of thinking (that needs development of scientific attitude), and a process of inquiry (that needs nurturing of science process skills).

Unit 4: Science in School Curriculum starts with the discussion on the development of science education and aspects related to teaching of science mentioned in the NCF-2005. The unit will also discuss the status of science education and perception about present science curriculum. Similarly, the unit will also discuss the recent curricular changes in science, difference in science curriculum at various stages of schooling and ways of integrating science to other subjects while teaching.

UNIT 1 SCIENCE: PERSPECTIVES AND NATURE

Structure

1.1 INTRODUCTION

Science as a discipline has its unique perspective. Science is not limited to observation, experimentation and analysis only; rather it is a way of life. Science is an expanding body of knowledge through process of inquiry. A Science teacher should understand all its dimensions. Present unit will discuss in detail about meaning and nature of Science and facilitate you in resolving myths related to Science. The Unit also explains the process of scientific inquiry, as well deliberates on place of Science in society. It will facilitate you in developing understanding of relationship of Science and society in learners' minds. Science has its own values system, which will be discussed in this unit.

1.2 OBJECTIVES

After going through this unit, you will be able to:

- facilitate your learners in understanding meaning of Science,
- explain various domains of Science,
- explain Science as a process of inquiry,
- identify and resolve myths related to nature of Science in learner's mind,
- help your learners in realizing place of Science in the society, and
- identify and inculcate scientific values among your learners.

1.3 UNDERSTANDING SCIENCE

Being a Science teacher, your first responsibility is to facilitate your learners in understanding the Science. Science is not a new subject for them, as it has already been introduced to them at upper primary (Class VI-VIII) level. The focus of Science teaching at elementary level was on engaging learners in learning principles of Science through familiar experiences, working with hands-on to design simple technological units and modules and continuing to learn more on environment and health through various activities (NCF-2005). At Secondary level, you have to engage your learners in learning Science as a **composite discipline** i.e. as an integrated discipline Science and not as segregated subjects like Physics, Chemistry, Biology, etc. They need to understand the nature of Science as well as what comes under domain of Science. Let us discuss, how will you facilitate them in understanding what is Science?

1.3.1 What is Science?

Perhaps, India may be the only nation with a constitutional provision as fundamental duty 'to develop scientific temper' among its citizens. Article 51A (h) is: ***"To develop the scientific temper, humanism and the spirit of inquiry and reform"***. This reflects how we thought about Science. For us, Science is neither a pedagogical discipline nor a group of certain subjects. We have perceived Science as a way of life with rational thinking. This feeling and understanding should be inculcated among learners since childhood so that they can perceive Science as a part of their life. Our scientific traditions are ancient and our perception about Science is associated with the notions like logic, rationality, truth, knowledge and intelligence.

It is never easy to answer the question, what exactly the Science is. For some Science is what the scientists practice. For others, it is organized knowledge disciplines like Physics, Chemistry, Biology, etc., but no one can answer this question exactly. This leads us to think bit deeper.

Etymologically word 'Science' has been derived from the Latin word '***scientia***' which means 'knowing'. Before the 18th century, Science was referred as 'natural philosophy'. Still for some, it is a title; for some, it is a concept, few perceive it as a method or process while for some, it is inquiry. If we go through philosophical origin and understanding of term 'Science', we can see various perceptions about Science and this makes it more interesting and challenging. Similarly, when you look back towards your own childhood and school days, you can find, what was your own perception about Science.

When your teachers introduced Science as a subject for systematic study and divided it into many areas like: Physics, Chemistry, Zoology, Botany, do you think, at that time, you understood what Science is? Many of you may answer in the negative. Now how will you answer the question: What is Science?

Let us reflect on it. Science is a process of learning. It is very different from other areas of study because "***the way to learn Science is to do Science***". You can propose it as subject, which always tests ideas with the help of evidences collected

from the worlds around us. Some of the important characteristics of Science which need to be shared with learners are:

- You can help learners to understand that Science does not explain supernatural myths rather it focuses on the natural world around them. For example, Science helps to understand growth in plants, characteristics of animals, etc.
- Learners should understand that Science is not merely a collection of evidences of happenings; rather it attempts to understand happening through analysis, testing and verification.
- You can give examples of Scientists working in different areas and ask learners to find out what is common in their working. Learners will soon realize that scientists work on testing of ideas, that are generated and their verification with the help of evidences generated or collected.

Science is actually an integral part of our daily life. As a teacher you can help learners to understand that scientists are as human as we. They also have feelings of joy, rivalry, competition, success, failure, etc. as any human being.

As a teacher of Science at secondary level, you should ensure that learners should overcome the traditional stereotype/mental blocks related to Science like Science text books are heavy, scientists are persons wearing lab coats and working on microscopes, a natural scientist works in the rainforest, or busy in writing some equations and formula on a chalkboard…. all such images are the reflection of one aspect of Science, but do not offer a full picture.

It is always a debate that what is Science and what is not. As a Science teacher, we must think on certain issues like why there is no suffix 'Science' with subjects like Physics, Chemistry, Biology, Zoology, Botany, etc., and why there is always a suffix 'Science' with subjects like Social Science, Political Science, Management Science, Environmental Science, Health Science, Library Science, etc.

> In a public lecture at the Indian Institute of Science, Banglore, in January, 2010, David Gross, the celebrated theoretical physicist and winner of Nobel Prize for Physics in 2004, narrated an interesting incident in the life of John Nash. Nash was winner of 'Nobel Prize for Economics'. One journalist asked Prof Nash: "do you agree that economics was a Science?" (because the prize was given for Economic Science.) Nash apparently replied that any subject which needed to have the appendage 'Science' to it could not really be a Science. Gross then went on to say how the disciplines of Physics, Chemistry, Mathematics and Biology did not have the addition of 'Science' to them whereas 'Social Science' did.
>
> ***Defining Science, p.1., in Sarukkai, S. (2014). What is Science?, NBT, India***

As teachers of Science, you should also reflect such questions and identify the elements which justify the addition of 'Science' as suffix to any subject.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

1) Do you agree that Library Science is a Science? Give arguments in support of your answer.

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1.3.2 Myths about Nature of Science

In order to present nature of Science to learners, a teacher can keep in mind what McComos (1998) proposed 15 incorrect ideas about Science.

Table 1.1: Myths about Nature of Science (McComos, 1998)

S.No	Myth about nature of Science
1	Hypotheses become theories that in turn become laws.
2	Scientific laws and other such ideas are absolute.
3	A hypothesis is an educated guess.
4	A general and universal scientific method exists.
5	Evidence accumulated carefully will result in sure knowledge.
6	Science and its methods provide absolute proof.
7	Science is procedural more than creative.
8	Science and its methods can answer all questions.
9	Scientists are particularly objective.
10	Experiments are the principal route to scientific knowledge.
11	Scientific conclusions are reviewed for accuracy.
12	Acceptance of new scientific knowledge is straightforward.
13	Science models represent reality.
14	Science and technology are identical.
15	Science is a solitary pursuit.

It is important to understand the role of these myths in understanding the nature of Science and in planning how these can be discussed with learners. What kind of activities you will organize so that learners can understand that these statements are only myths. Let us discuss a few myths as examples and discuss activities/ examples/illustrations, which can be used in the classroom.

One of the most common myths about the nature of Science is that ***"a general and universal scientific method exists".*** Many times teachers and learners in Science have the view that there is a common series of steps that scientists follow in their investigations/research. In most text books of Science, initial chapters talk about the general steps of a scientific method i.e. defining the problem, forming a hypothesis, making observations, testing the hypothesis, drawing conclusions and reporting results. Slowly classroom and laboratory practices adopt this procedure of writing up the aims, hypothesis, method, results and conclusion. This, in the long run, turns into a wrong belief that a general and universal scientific method exists.

There is another common myth that ***"scientific laws and other such ideas are absolute".*** This has also taken the shape due to misconceptions and traditional way of teaching Science. In teaching learning Science, our focus remains on universal laws and theories. Even the cover page of various Science related books often reflects some equations like $E=mc^2$ and picture of law of gravitation or the Archimedes principle. An emphasis on the principles and theories which are of universal nature gives birth to such misconceptions.

As a teacher you need to appreciate that scientific knowledge is tentative not absolute. An example like the journey of atoms to subatomic particles is a case in point. Initially, atoms were considered as ultimate small particle of any elements. Later discoveries of electron, protons and neutrons as sub atomic particles. You must have read about the experiment in search of Boson or God particle by collision of sub atomic particles. Another very interesting example which you can use is the periodic table. Initially in Mendeleev's table, the number of elements was around 60, but the number has gone up to 118 and is still increasing. Similar examples can be used to establish the tentative nature of scientific knowledge.

1.3.3 Understanding Nature of Science

Generally speaking, nature of Science is a fundamental domain for guiding Science teachers in accurately portraying Science to learners. Science learners need to know not only facts/concepts but also about the processes through which this knowledge is generated. Thus, appropriate knowledge of nature of Science can help a teacher in enhancing her ability to implement conceptual changes and also in understanding learners' learning (Matthews, 1994).

Understanding nature of Science is important because if your understanding and the Philosophy of Science is not congruent with the current interpretations of the nature of Science, you will not be able to do justice to explanations and interpretations of scientific issues in scientific terms.

With more focus of constructivist approach for knowledge creation, a teacher has to understand various aspects of nature of Science so that s/he will be able to create or generate opportunities for knowledge for learners. It has been observed that introduction in Science imparted to learners depends upon the teachers' own views of the nature of Science (Gill, 1977, p. 4). Hence, enhancing teachers' understanding of nature of Science is clearly a prerequisite for effective teaching learning process in Science.

Understanding of nature of Science is also important for two reasons; one is curricular, that is what kind and amount of content is appropriate according to the cognitive level of learners and the second, to plan right kind of learning situations for learners i.e. the teaching learning strategies to be adopted. It is challenging task for a teacher to translate the understanding of Science into a knowledge generation opportunity for learners. A broad understanding can help you in designing meaningful situations and in selecting appropriate tools for classroom transition.

What is nature of Science? This is a debatable issue since long but an accurate description of the function, processes and limits of Science can engage learners' interest in the issue.

Aspects of nature of Science have been identified and explained by many researchers but the following list seems to be fit in our objective. Table 1.2 shows the convergent aspects of the nature of Science (identified by Lederman, 1992;McComos, 1998).

Table 1.2: Aspects of Nature of Science

S.No.	Aspects of Nature of Science
1	Scientific knowledge is long lasting yet tentative
2	Empirical evidence is used to refine and support ideas in Science
3	Social and historical factors play a role in the construction of scientific knowledge
4	Laws and theories play a central role in developing scientific knowledge, yet they have different functions
5	Accurate record keeping, peer review, and replication of experiments help to validate scientific ideas
6	Science is a creative endeavor
7	Science and Technology are not the same, but they have impact on each other

Let us analyze few of these characteristics.

Scientific Knowledge is Tentative

Scientific knowledge is subject to change. Why is it so? It is so because; we make new observations and tend to reinterpret the existing observations.

- Solar system is a very common topic, while discussing the Solar system; teachers can emphasize that now there are eight planets but earlier ninth planet Pluto also existed. But in 2006 Scientists reclassified it as a 'Dwarf Planet'. Astronomers discovered an object in the Kuiper belt which was larger than the former ninth planet Pluto and therefore Pluto was not given the status of a planet. This means Science is tentative – its facts, theories are subject to change in the light of new observations and new findings.

- Evolution and connecting links are some other common themes in Science. The tentative nature of Science can be emphasized by discussing many more examples. Let us discuss the case of 'dinosaurs'. Dinosaurs were earlier

believed to have evolved from reptiles (group to which lizards, snakes etc. belong) but now the perception about their lineage has changed. Today scientists are of the opinion that they have evolved from birds. Archaeopteryx, a feathered dinosaur, was discovered in Germany in 1861. Archaeopteryx forms a connecting link between two vertebrate groups – reptiles and birds. It has some reptilian features like presence of teeth and beak. The avian features include presence of wings and beak. John Ostrom from Yale University in late 1960s found 22 features in the skeletons of meat-eating dinosaurs which are only seen in birds. This forms the basis of bird lineage of dinosaurs.

Above examples support the argument that Science is tentative and subject to change but there are certain scientific ideas which have stood the test of time. Sir Isaac Newton's three laws of motion have survived the test of time. Although these laws have also been modified, instead of force at a distance, the concept of field has been introduced. As a Science teacher, you have to present both sides of the coin because there are certain scientific principles of universal application.

Activity 1

Present few examples to reflect that nature of Science is tentative and also few examples to show universal nature of few scientific principles (From Science text book of class IX or X. Ask your learner to compare both the situations and enlist few key differences in them.

Observations of the Natural World

Learners should be given enough opportunities to understand the difference between observations and inferences. For instance, you can show them different types of plants like a desert plant, a water plant, a climber, etc. and ask learners to make a list of observations about the these three different plants. Divide their answers into two lists: one labeled 'Observations' and the other 'Inferences.'

Table 1.3: Examples of Observations and Inferences

Observations	Inferences
A Desert Plant	
Very small sized leaves	Small sized leaves help in reducing loss of water
A Water Plant	
Leaves are covered with waxy coating	Waxy coating helps in preventing decay in water
A Climbing Plant	
Thread like spirally coiled structures are arising from the stem of the plant	These spirally coiled structures (tendrils) help in providing support to the plant

As a teacher, we can see the difference between an observation and inference. Observation is what one sees and inference is making a conclusion based on the basis of what one has seen. Let us consider the following example.

Case 1

Ms. Poonam is a Science teacher in a Nigam PratibhaVidhyalaya in semi urban area of South Delhi. Once she arranged a fun trip to Qutub Minar for her learners. In the Qutub complex, the learners saw an iron pillar. Ms. Poonam asked the learners to note down the details displayed about the pillar. It was stated that it is around 1600 years old and rust resistant. After returning to school, Ms. Poonam asked the learners to enlist those iron items in their house, which are being used regularly and are rusted. Learners presented a number of examples. She then asked them to compare their details about the iron pillar at Qutub complex with examples of iron items at their house. Then she introduced the concept of rusting of metals.

As a teacher, you can identify and use many such opportunities from the nearby region to introduce simple concepts of Science. At secondary level, Science should be evolved from natural contexts of the learners and also from laboratory experiments, theoretical principles and processes, but if examples are close to their immediate natural environment, Science will become interesting and understandable for learners.

Activity 2

Identify some topics from the Science textbook of class IX. Plan some visits to the nearby areas to provide the learners a feel that the content in text book is of their immediate use and they can observe its implications in the natural environment.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

5) List any five common myths about nature of Science.

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1.3.4 Domains of Science

To think of Science, we have to take into account its multidimensionality. All though it is more application oriented, but also based on sound theoretical, philosophical and sociological parameters. You must have gone through Unit 2 i.e. Perspectives of Disciplinary Knowledge (Course BES-125: Understanding Disciplines and Subjects), where these aspects are discussed in detail. Whenever we talk about Science, three interwoven domains come to our mind (as shown in Figure 1.1).

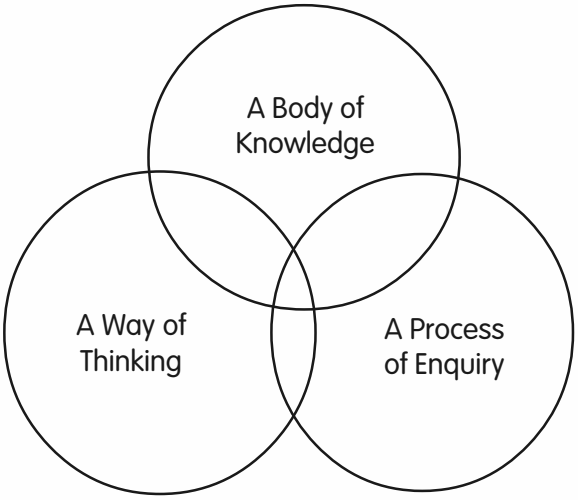

Figure 1.1: Three Domains of Science

Let us try to understand what these domains are. In order to do so, we have to enlist various activities, facts, and processes related to Science. You can think of scientific facts, concepts, theories, laws and some methods and processes. However, when describing the nature of Science, educators have converged on a key set of concepts, like: **tentativeness, empirical evidence, observation and inference, scientific laws and theories, scientific method, creativity, objectivity and subjectivity,**etc. All these can figure in the three major domains of Science, as shown in Figure1.2.

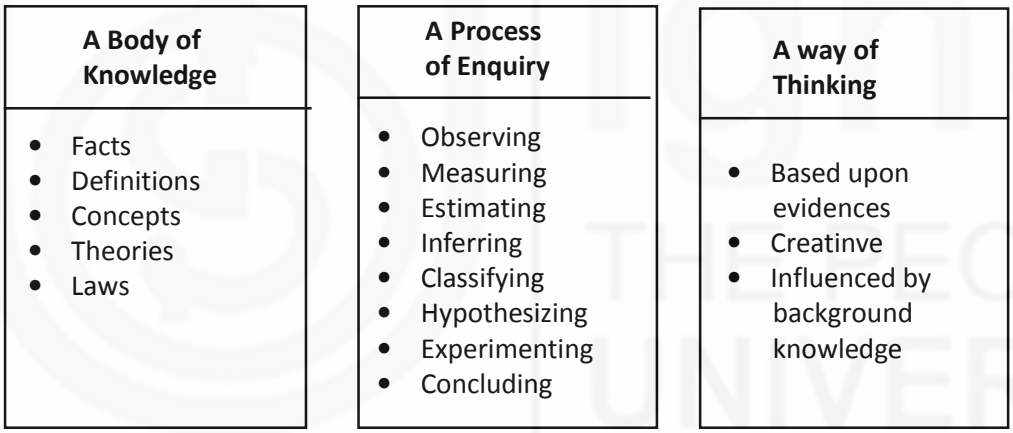

Figure 1.2: Nature of Science

Let us discuss each domain in detail:

Science as a body of knowledge

First domain represents the nature of Science as a body of knowledge. Generally we take Science as a body, which includes facts, definitions, concepts, principles, theories, laws etc. You must have come across many people talking about 'Scientific knowledge' about the planet, stars, etc. If you see any textbook on Science, you can easily find various facts, concepts, definitions, principles and theories associated with Science. A few of them have lasted long and have been a part of scientific knowledge since generations. Some important characteristics of scientific knowledge are:

- It is tentative

- Scientific ideas are influenced by social and historical background.
- The Objective of Science is to provide explanation of natural phenomena whereas the objective of technology is to provide solutions of problems related to life.

Sometimes, while responding to the questions raised by learners, we try to satisfy by telling them to just remember the fact or principle, if they are unable understand it; do you ever think that only the factual information can satisfy them completely? By emphasizing on theories and principles, you can provide only factual knowledge to learners, which is of no use to them. This only creates a burden on learners' minds and gradually they start losing interest in Science (Larsen and Cindy, 2011). It is the high time that you should come up with the strategy to provide them with real experience of Science. You should provide learners an opportunity to feel, experience, explore and analyze. They will themselves generalize and develop their own body of knowledge. If you want to establish Science as a body of knowledge, you have to plan such activities, in which learners find out the concepts, principles and theories after generalizing by themselves.

Activity 3

Take the Science textbook of class IX. Enlist the facts, concepts, definitions, principles and theories presented in the chapter 'Acids, Bases and Salts'. How will you present them as a body of scientific knowledge to your learners?

Science as a process of inquiry

Another domain is Science as a process of inquiry, though we will discuss it in details in the next section of the Unit; let's try to understand here, why Science is considered as a process of inquiry.

When you start teaching and learning of Science in your class, you have to go through various processes, which will allow your learners to investigate about various important issues in their surroundings. Certain process skills have to be developed like 'Observation, Inference, Classification, Communication, Measurement, Prediction', etc. These skills will be discussed in details in the Unit 3.

The process skills are important for scientific investigations and in everyday life. The learners should be able to establish causal relationships and distinguish them from mere associations.

In a Science classroom, the teacher is expected to provide opportunities to the learners to participate in some investigative activities which will help them to understand the nature of scientific inquiry. Such practices will encourage the learners to think about the relationships between facts, options, processes and incidents. It is expected that you will encourage your learners to identify relationships and analyze rationally the associated facts.

Science as a way of thinking

The third domain is Science as a way of thinking. Famous scientist Carl Sagan says that *"Science is more than a body of knowledge. It is a way of thinking."* On a wider note, you have to work for development of scientific thinking among your learners. Your success as a Science teacher will depend upon the degree of scientific thinking and scientific attitude developed in your learners. In previous

sub-sections, our focus was to establish Science as a body of knowledge and a process of inquiry but both these aspects are closely related to third one i.e. Science as a way of thinking.

Scientific way of thinking can be promoted by making our learners able to explore, analyze, evaluate and work in a scientific manner. Scientific way of thinking will make our learners collect evidence that can be physically observed and measured. This is known as empirical evidence. Scientific way of thinking also allows starting questioning why and how things are as they are.

Science as a way of thinking involves scientific temper, scientific inquiry, and a sense of humanity, accepting that scientific ideas are tentative and control of emotions while interpreting the evidences are its important ingredients. The discussion above clearly indicates that no domain can be segregated from the other and all three are integrated.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

2) Suggest some classroom activities, which will demonstrate Science as a body of knowledge, a process of inquiry and a way of thinking.

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1.4 HOW SCIENCE WORKS?

As a Science teacher, first myth you have to resolve in your classroom that Science is not something that develops through scientific method only. There are examples, where scientific discoveries and inventions are not a product of any systematic scientific method. Examples given below can help you in resolving this myth among your learners. Learners must have studied a traditional 5-step scientific method which includes: 'Problem, Hypothesis, Experimentation, Observation and Results.' It has been observed that many learners develop a misconception that every scientific study takes place through these steps only. Your role as a Science teacher is to help them in coming out of this myth.

Let us discuss few path breaking inventions and discoveries of Science and how did they take place.

Law of Gravitation

In the biography of Newton entitled *Memoirs of Sir Isaac Newton's Life* written by William Stukeley, an archaeologist and one of Newton's first biographers and published in 1752, Newton told the apple story to Stukeley, who relayed it as such:

"After dinner, the weather being warm, we went into the garden and drank tea, under the shade of some apple trees...he told me, he was just in the same situation, as when formerly, the notion of gravitation came into his mind. It was occasion'd by the fall of an apple, as he sat in contemplative mood. Why should that apple always descend perpendicularly to the ground, thought he to himself..."

Source: *https://www.newscientist.com/blogs/culturelab/2010/01/newtons-apple-the-real-story.html*

Discovery of Penicillin

Scottish biologist Alexander Fleming took a break from his lab work investigating staphylococci and went on holiday. When he returned, he found that one Petri dish had been left open, and a blue-green mould had formed. This fungus had killed off all surrounding bacteria in the culture. The mould contained a powerful antibiotic, penicillin, which could kill harmful bacteria without having a toxic effect on the human body.

Source: https://newhumanist.org.uk/articles/4852/Science-and-serendipity-famous-accidental-discoveries

Radioactivity

French scientist Henri Becquerel was working on phosphorescent materials, which glow in the dark after exposure to light. The chance discovery came during an experiment involving a uranium-enriched crystal. He believed sunlight was the reason that the crystal would burn its image on a photographic plate.

One stormy day in 1896, he decided to leave it for the day and resume his experiments when the weather was better. A few days later, he took his crystal out of a darkened drawer. The image burned on the plate was "fogged" – the crystal had still emitted rays, despite the lack of sunlight. It was clear that there was a form of invisible radiation that could pass through paper, causing the plate to react as if exposed to light.

His research was continued by Pierre and Marie Curie, who named the phenomenon radioactivity.

Source: https://newhumanist.org.uk/articles/4852/Science-and-serendipity-famous-accidental-discoveries

The Microwave

The heating effect of a high-power microwave beam was discovered in 1945 by Percy Spencer, an American engineer working for the company Raytheon. He was working on a magnetron capable of beaming high waves of radiation, when he noticed that a chocolate bar in his pocket had melted. Curious, he

placed a bowl of popcorn in front of the tube and it began to pop. Spencer then created a high-density electromagnetic field by feeding microwave power from a magnetron into a metal box from which it could not escape. When food was placed in the box, its temperature quickly rose. In October that year, Raytheon patented the technology and it became available to the public in 1947.

Source: *https://newhumanist.org.uk/articles/4852/Science-and-serendipity-famous-accidental-discoveries*

What inference your learners can draw from many such stories?

You can use many such stories to help your learners in understanding that every discovery or invention is not a linear process. Sometimes, it is an observation (like law of gravitation), sometimes it may a critical question or a systematic inquiry (like radioactivity), which results into a discovery or invention, but yes, they have to follow scientific method to test, validate or establish any theory.

As a teacher of Science, you should provide them opportunity to discover Science in their surroundings by using a process of inquiry.

1.5 SCIENCE AS A PROCESS OF INQUIRY

Why moon usually comes at night? Why flowers are of many colours? Why we feel hot or cold? How does it rain? etc. are a few questions, which teachers have come across while dealing with learners in classroom. These questions are a reflection of curiosity among learners about the incidents in their surroundings. Being curious is a natural tendency of the learner, it drives him/her to find out answer of these questions either by exploring something or asking adults and teachers. This curiosity is at the center of inquiry.

Inquiry learning refers to finding an answer of a question in mind using various resources from surroundings to access information, data, knowledge and idea. These resources may be in the form of daily experiences, books, pictures, texts, stories, local animals and plants, things around them, diagrams, animations, video, movie clips, newspapers, etc. We can say that inquiry based learning promotes knowledge formation and its generation. Scientific inquiry is a way to investigate things and propose explanations for observations. When learners are engaged in scientific inquiry, they may think that there is a usual set of procedures to follow, that is the scientific method – suggest hypotheses, design an experiment, record observations, get data, analyze it and firmly draw conclusions. But this is not the only procedure. In scientific inquiry, they may follow other approaches to solve a problem or to seek answer of a question in mind.

Scientific inquiry may be considered as an approach to reach to a solution of the problem, but it is not essential that all people will follow the same route. In this sense, it can be said that scientific inquiry provides freedom in approach to deal with a problem. It is a process with many variations depending upon needs, experience, prior knowledge, available resources, personal likings and objectives. How does scientific inquiry work in young learners? Worth and Grollman (2003) through a simple inquiry learning model, answered this question.

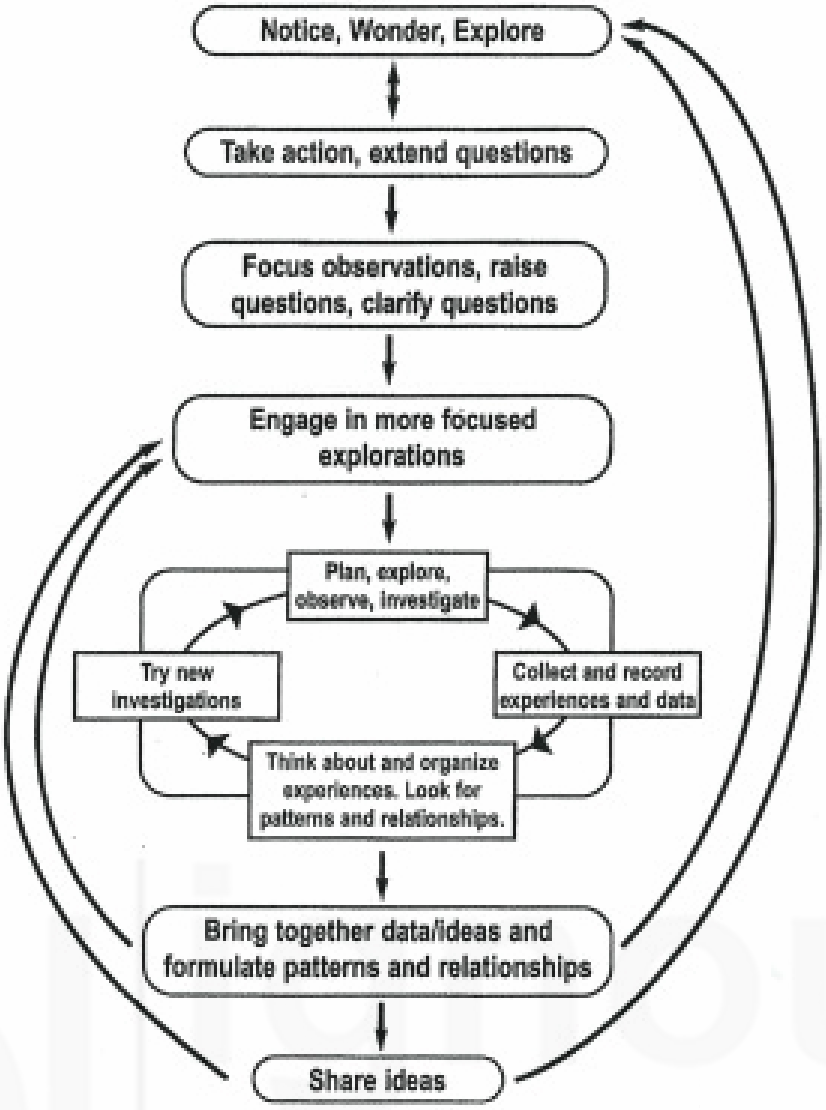

Fig. 1.3: Inquiry Learning Cycle (Worth &Grollman, 2003, p. 19)

If you go through this cycle, you will observe that learners learn through inquiry which begins with some incident they notice. It initiates a process of question formation in their mind, which they ask to themselves first and then to elders. It guides them to move on to next step of focused exploration and investigation. They collect data, information and analyze it to draw a conclusion. They correlate their observations with data, formulate patterns and find out relationships and share their ideas with their peers as well as teachers. Similar procedure is adopted by scientists, but yes with some sophistication.

Thus, we can say that scientific inquiry helps learners to develop a variety of skills. Few of them may be like exploration of objects, things, incident, questioning, careful observation, engaging in simple investigations, ability to describe, compare, analyze and classify, recording observation, using tools for data collection, identifying patterns and relationships, drawing out tentative conclusions, etc.

In order to understand the process of scientific inquiry in more specific terms, let us discuss various processes such as formulation of hypotheses, gathering of

data, recording of observations, reaching to conclusions, etc. which one has to undergo during scientific inquiry.

Constructing explanations and ideas

The very first process, which a learner undergoes in this process, is the construction of explanations and ideas. Let us see, how it takes place.

> *In a Science class, the Science teacher Mr. Moin, brought some material. It was a water bottle, a glass and a thick paper sheet. He poured water in the glass and put the thick paper sheet on it. Slowly and carefully, he inverted the glass and removed his hand from there. Learners were surprised that paper had stuck on the glass and water is not coming out.*
>
> *He asked learner to reflect on it.*
>
> *Learners started discussing by giving explanations for their observation.*
>
> *The responses were varied.*
>
> *Some said that paper had glue inside.*
>
> *Some said, it had stuck due to water inside.*
>
> *Others whispered that there was some other thing in the water bottle.*
>
> *For some it was a kind of a magical trick.*

What are these comments? As a Science teacher, how can you use their comments for generating interest in natural phenomenon?

These comments/observations are part of the process of developing ideas and construction of explanations. As a teacher, you must have understood that Mr. Moin was exhibiting the phenomenon of air and its pressure. You may not accept these explanations of learners as 'scientific explanations' but you agree that this is how the process of scientific explanations starts. In scientific process, explanations are based on some scientific evidence and observations are supported by theories and experiences.

During scientific explanations, scientists use evidence to establish relationships and causes of phenomena. Scientific explanations must always be based on evidence. These evidences can come from designing and conducting an investigation; observing a demonstration; collecting specimens; or observing and describing objects, organisms, or events.

In case of learners, their explanations may not be 'scientifically sound' but you have to encourage them for generating explanations based on their observation and previous scientific knowledge. How will you do this?

You will either ask them a few questions or give response to their questions in scientific way. In both the cases, you have to know the art of asking question and developing appropriate questions. In next subsection, we will focus on this very aspect of scientific inquiry.

Asking questions and using appropriate questioning technique

Generally in a Science classroom, various 'vague' ideas and explanations proposed by learners are not accepted by teachers. Learners have a natural tendency to ask

questions. Teacher can also ask questions to learners as a part of scientific inquiry. As a teacher of Science, you have to first understand a variety of question that can be asked or answered. There are two types of questions that can be asked in the classroom: Existence and Casual.

Existence questions start with *why* and are answered on the basis of recalling factual knowledge a learner already have. On the other hand **casual** questions begin with *how, what if, does* and *I wonder,* which are generally answered through scientific investigations.

In scientific inquiry, questions are a bit different from the questions generally asked. When a learner develops his/her understanding about scientific inquiry, s/he is able to generate his/her own set of questions. Generally, following types of questions are asked during scientific inquiry.

Testable Questions: These questions can be tested and can be answered through evidence based on observations or experimentation. These question lead to formation of hypotheses. For example, Can fish survive out of water?

Spontaneous questions: Questions raised by learners as reflection of their natural curiosity towards any incidence or phenomenon. For example: Why flowers are not green?

Stimulative Questions: These questions are generally asked by the teacher to stimulate learner thinking, observation and reflection towards provided material or demonstration. For example, the teacher may ask after a demonstration: Why paper boat floats and paper sinks?

Factual questions: Questions related to any scientific fact to justify any phenomenon.

Generally, learners ask factual questions as they are not aware about the actual process of scientific inquiry. Factual questions are comparatively easy to generate. As a teacher you have to encourage learners to ask more meaningful questions. As soon as learners will learn to ask a variety of questions, they will also learn to relate the questions with scientific inquiry process and investigations. They should be provided opportunities to explore information related to their questions and should be encouraged to find answers of their questions by themselves. Along with it, the teacher should try to modify factual questions into testable questions and provide opportunity to generate new questions.

Activity 2

Initiate a discussion on any topic (e.g. rain, air pollution, etc.) related to Science in your class. List the questions asked by learners. Categorize these questions into various types of questions mentioned above.

Developing testable questions and hypotheses

As discussed in the previous sub-section, in the process of scientific inquiry, the teacher has to develop testable questions. We have discussed that testable questions are answered through observations or experiments which provide evidence.

It is also suggested that you direct your learners to be able to distinguish between testable questions and other forms of questions and factual questions asked by learners should be modified into testable questions. Let us first try to understand what is a testable question?

BSCS (2005, p. 30) has suggested that a testable question meets these criteria:

- The question centers on objects, organisms and events in the natural world.
- The question connects to scientific concepts rather than to opinions, feelings, or beliefs.
- The question can be investigated through experiments or observations.
- The question leads to gathering evidence and using data to explain how the natural world works.

Can you apply these criteria on the questions discussed in previous section?

Many times, you can observe that the questions are mostly related to an activity but cannot be accepted as testable questions because these can't be answered through an experiment only. There are a few questions, which can be answered on the basis of factual knowledge and explanation of cause-effect relationship.

Before answering the questions, the teacher has to provide an opportunity to learners to predict/give the probable answers of their questions. Learners may develop some predictions or tentative answers based on their observations. Some of their answers may be testable or not, the teacher has to help them in identifying the testable tentative answers. **These tentative or testable answers to the testable questions are often termed as hypotheses**.

According to Heyer (2006, p.4), the four most important things to remember about hypotheses are:

- A hypothesis should be consistent with existing observations and known information regarding the question.
- A hypothesis must be presented as a statement of the predicted outcome, not as a question.
- A hypothesis is formulated before the experiment, not after the experiment.
- A hypothesis must be specific and testable.

As a teacher you can create situations to encourage learners to form testable questions and find out probable answers on the basis of their observations and previous knowledge.

Activity 3

In order to encourage your learners for framing hypotheses, you can perform activities in the classroom based on:

- The increase in the rate of evaporation of water with heat.
- Factors affecting growth of salt crystal.
- Factors affecting growth of plants/seed germination.
- Effect of exercise on rate of respiration.

Planning, conducting and observing simple investigations

In order to test formulated hypotheses, you have to encourage learners to plan, conduct and observe some investigations or simple experiments. Whenever an investigation is to be carried out, it should be based on sound planning regarding the role of the teachers and learners and their participation during the investigation.

While planning any simple scientific investigation, you should prepare yourself by answering questions like:

- What is the objective of investigation?
- How is it related with scientific concept or theory?
- What are the required material/resources for investigation?
- Where will the investigation be carried out i.e. inside the classroom or outside the class/school?
- What will be the level of involvement of the learners?
- What will be role of learners?
- What are the precautions to be kept in mind? And so on…

After planning, the next task is to conduct the activity i.e. executing your plan. To encourage learners to be active participants of investigation, the teachers should guide them to perform the investigation. The activity set by the teacher should ensure the active and enthusiastic involvement of the learners in observation, establishing cause-effect relationship, collecting information, arranging data in sequential and logical manner etc. Teachers' role should be of a vigilant observer with minimum interference in the process of investigation.

It has been suggested that the teacher not only connects classroom teaching with the physical surroundings but also promotes the investigation by learners, helping them to establish a relationship with their surroundings.

As a teacher, you can perform many simple experiments in the classroom also. Some of them could be:

- Take two test tubes leveled as A and B. In test tube A, put some boiled rice, and in B, put the boiled rice after chewing it for 3-5 min. Add 3-4 ml. water in both. Now pour 2-3 drops of iodine solution in them. Ask the learners to observe the change. You can explain the role of saliva in breaking of **starch into sugar**.
- Take one iron rod. Apply wax on it and attach some nails with the wax. Start heating one end of the rod. Ask the learners to observe the changes. You can help them to understand the concept of **flow of heat.**

These are just a few suggestions; you can plan a lot more activities based on the content of the prescribed Science Textbook. The objective of discussion in this section is to sensitize you about making teaching learning more inquiry based and making the learner an active constructor of scientific knowledge.

Constructing explanations and communicating results

After completing the investigation, encourage learners to communicate about the conclusions obtained and justify the proposed explanations. You can tell

them that conclusion is the culmination of the entire inquiry process. The conclusion should include all aspects- from the observations that lead to questions, investigation that leads to the hypothesis and the experiment and data which leads to the determination if the hypothesis has been accepted or rejected. The conclusion also includes other questions that may have arisen in learners' mind during the course of the experiment/investigation and the experiences they might have undergone during the experiment.

After drawing conclusions, learners are expected to share and communicate the results obtained. Communicating results is another important part of scientific inquiry. Here it is not expected that learners should communicate the result in same way as the scientists communicate their results, all though, they have to learn to report their result in a sequential way in the light of objectives decided earlier. The teacher can help learners to present the results of their inquiry in an understandable form for others.

Solving problems

A learner of Science is expected to solve her/his day to day problems with a scientific attitude. S/he should apply the process of scientific inquiry in understanding, analyzing and solving a problem. As a teacher you have to create situations, in which learners feel encouraged to analyze the problem in a scientific process, apply scientific inquiry approach to understand it, formulate testable questions and hypotheses, organize scientific investigation, draw a conclusion and report it as a solution of the problem.

It should be remembered that scientific inquiry only leads us towards possible solution of problems and we have to decide whether it is right or wrong based on evidences, observations and experimentation.

The question is how can we motivate learners towards it? Through a problematic situation of their day to day life, incidents from their surroundings, news clips, newspaper reports, natural disasters, linkage of scientific concept explained in text book with the examples of their life experiences, we can motivate learners. Here are some examples given in the box, where a scientific concept can be explained with the help of every day experiences.

Concept	**Example form daily life experience**
Food material and sources	Analysis of meals
Solute, solvent and solution	During summer Home-made drinks
Separation of substances	Tea separation, butter formation, threshing
Different habitats of animals of animals in their surroundings	Visit to the zoo and close observation
Magnet	Doors of refrigerators, pin holders
Food chain and food web	Grassland, pond or forest visit

If you analyze the content given in your Science textbook, you can find many such examples.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

3) What are the types of questions in scientific inquiry?

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4) What should be the characteristics of a good conclusion?

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1.6 SCIENCE IN SOCIETY

As a teacher of Science, your role is to help your learners in understanding the relationship of Science with society. Science is not something which has emerged on its own. There is an important role of needs and demands of society in development of Science.

Science has developed for facilitating society in explaining various natural phenomena. In our own Indian literature, there are examples from *Rigveda*, where it has been explained that how Earth rotates around Sun in 12 months. There are slokas and verses in Kalpsutra which have explained many relationships of squares, triangles, circles, even many years before Pythagoras. How Aurveda and Surgery were being used to help society in being healthy, there are books on it. In modern Science, Have you read a famous book '***A brief History of Time'*** by Stephen Hawking, or can you imagine the impact of '***Origin of Species'*** written by Charles Darwin. These are few examples to initiate the discussion on relationship of Science and society. Science is a social enterprise; this is to be explained for learners by you as a Science teacher.

Innovations and discoveries of Science have transformed the whole social structure.

- Can you compare the society before and after the invention of mobile phone? How mobile phone technology as changed the whole social structure.

- Can you compare the year when only books and newspapers were source of information and now when internet and social media has become major source of information?

- Can you imagine the contribution of Science in the area of medical Sciences, where every day something new is being invented in form of vaccine, medicines, surgical equipment, and diagnostic test kits, etc.?
- How do recent developments in Space and Atomic research affect the social relationships in global world?

There are many such questions, which may emerge in your mind when you start thinking about relationship of Science and society.

You will not find any aspect of social or personal life, which is not affected by innovations and discoveries in Science.

Ask your learners to perform a small activity.

Ask your learners to list down various duties they perform as a member of society, and also enlist the scientific discoveries/inventions which are helping them in performing their duties:

Duty	Their Role	Scientific discoveries/inventions, which help

You can organize many such activities where they can learn how important Science is for the society. You can invite Doctors, Agriculture Experts, Engineers, Environmentalists, etc. for talks so that learners can develop an understanding of their contribution in the society.

Activity

Organize any of the following events at your school in collaboration with society members:

- Science exhibition
- Discussion on role of various types of scientific discoveries/inventions for benefit of society
- Small group projects on latest development in Science and technology
- Reading circles about contribution of various scientists to society
- Poster Competition on contribution of Indian Scientists to the world

These activities will help you a lot in developing a fair understanding of relationship of society and Science among your learners.

1.7 VALUE DEVELOPMENT THROUGH SCIENCE

Value development is always an area of concern. Responsibility of value development is on all teachers. There are values which are universal across the

disciplines as well as discipline specific also. There is a need to adopt integrated approach for value development in which values should not be taught as content rather they should be imbibed in the process and activities of various subjects. Your role as teacher at secondary level is to facilitate learners with such activities where they can not only create knowledge and develop understanding of scientific phenomenon but also inculcate values among themselves.

A good Science curriculum should promote values like honesty, co-operation, objectivity, freedom from fear and prejudice, and develop in the learner a concern for life and preservation of environment (National Focus Group on Teaching of Science, 2006, p. 3)

Let us discuss few activities through which a Science teacher can inculcate values among learners. You have to complete the following table.

S.No.	Activity	Associated Value
1		Honesty
2		Interdependence
3	A group project on flora and fauna of tropical forest	Co-operation
4		Objectivity
5	Seed generation in a pot, Awareness campaign on cleanliness, Role play for awareness about wastage of water, Small project on natural disasters and their impact on human life, etc.	Environmental concern
6		Freedom from prejudices
7	Inspirational short stories from life of various scientists like Jagdish Chandra Bose, C. V. Raman, A.P.J. Abdul Kalam, Madam Curie, while teaching the scientific concepts related to their area of work.	Concern for life

With the help of this, activity you can understand that value development is possible by visualizing and integrating value development with teaching-learning process. You will also agree that a value cannot be developed by any one particular activity or a section of content; continuous efforts are required for it. It is expected from you being a teacher of Science that whenever you plan your teaching-learning process for any content, you will also plan the value associated with it and also the assessment strategy. If you keep it in mind during planning and transaction, you will be able to develop desired values among your learners.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

5) What are the major contributions of Science to modern Society?

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6) What are the values, which you can plan to develop through teaching-learning of Science at secondary level? Give suitable examples from content of Science textbooks.

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1.8 LETS US SUM UP

Unit has discussed in brief about meaning and nature of Science. It is suggested that as a Science teacher, you should help learners in understanding the Science as a process of inquiry. Various myths about nature of Science are to be resolved so that learners can understand true nature of Science. Learners also realize that Science is not only the body of knowledge or a process of inquiry; rather it is a way of thinking. Unit explains with examples that Science does not work only through scientific method, rather it develops through process of inquiry. Unit discusses in brief that Science has developed for facilitating society in explaining various natural phenomena. With the help of inventions and discoveries, Science has transformed the whole social structure. It is suggested in the Unit that there are certain values, which are to be developed along with teaching-learning process of Science. As a Science teacher, you have to integrate values development with content transaction in Science.

1.9. UNIT END EXERCISES

1) What are various myths related to Science? How will you help learners in resolving these myths? Give suitable examples.

2) Discuss various steps of inquiry with help of an example from secondary level Science curriculum.

3) How will you develop values while teaching Science? Explain with suitable examples.

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1.11 ANSWERS TO CHECK YOUR PROGRESS

1) Answer based on your understanding of section 1.3.1.
2) Discuss one classroom activity each for explaining Science as a body of knowledge, a process of inquiry and a way of thinking.
3) Testable Questions, Spontaneous questions, Stimulative Questions and Factual questions.
4) The conclusion should include all aspects from the observations that lead to the question, to the investigation that lead to the hypothesis and the experiment and data which lead to the determination if the hypothesis has been accepted or rejected.
5) Discuss major scientific contributions to society, which you observe.
6) Honesty, co-operation, objectivity, freedom from fear and prejudice, concern for life and preservation of environment.

UNIT 2 AIMS AND OBJECTIVES OF SCIENCE TEACHING-LEARNING

Structure

2.1 INTRODUCTION

In unit one, we have discussed about the meaning and nature of science. This unit aims to facilitate you in understanding the aims and objectives of science teaching. As a science teacher, you should be aware of why science is placed in secondary curriculum as an integrated area of study, how is it different from elementary level, etc. The Unit will facilitate you in formulating learning objectives according to Anderson and Krathwohl's taxonomy. Unit also discusses the shift in pedagogical approach from behaviourism to constructivism. How constructivist approach has affected nature of science teaching-learning, planning, methods and strategies and assessment, all such issues will be discussed in this unit.

2.2 OBJECTIVES

After going through this unit, you will be able to:

- understand aims and objectives of science teaching-learning;
- compare teaching of science at elementary and secondary level;
- formulate learning objectives in science;
- understand the shift in science pedagogy from behaviourist to constructivist approach; and
- analyse impact of constructivist pedagogy on nature of science teaching-learning, planning, methods and strategies and assessment, etc.

2.3 AIMS OF SCIENCE EDUCATION

National Curriculum Framework (NCF-2005) proposed five guiding principles for curriculum development:

i) connecting knowledge to life outside the school;

ii) ensuring that learning shifts away from rote methods;

iii) enriching the curriculum so that it goes beyond textbooks;

iv) making examinations more flexible and integrating them with classroom life; and

v) nurturing an overriding identity informed by caring concerns within the democratic polity of the country.

The entire teaching-learning process at school level revolves around these five guiding principles. NCF emphasized that "*teaching of science should be recast so that it enables children to examine and analyze everyday experiences. Concerns and issues pertaining to the environment should be emphasized in every subject and through a wide range of activities involving outdoor project work. Some of the information and understanding flowing from such projects could contribute to the elaboration of a publicly accessible, transparent database on India's environment, which would in turn become a most valuable educational resource. If well planned, many of these learner projects could lead to knowledge generation*."

It means, science teaching should be organized around learners' experiences and opportunities should be provided to learners to explore science around them. This marks a clear shift from classroom and laboratory centered science pedagogy. Integration in science teaching-learning is very important and scientific knowledge should not be compartmentalized in subject domains like physics, chemistry, biology, environmental science up to secondary level.

NCF-2005 and Position Paper of National Focus Group on Teaching of Science (2006) have proposed 6 criteria for validity of a science curriculum i.e. cognitive, content, process, historical, environmental and ethical. On this basis, following general aims of science education have been conceptualized:

Science education should enable the learner to:

- know the facts and principles of science and its applications, consistent with the stage of cognitive development,
- acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge,
- develop a historical and developmental perspective of science and to enable her to view science as a social enterprise,
- relate to the environment (natural environment, artifacts and people), local as well as global, and appreciate the issues at the interface of science, technology and society,
- acquire the requisite theoretical knowledge and practical technological skills to enter the world of work,

- nurture the natural curiosity, aesthetic sense and creativity in science and technology,
- imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment, and
- cultivate 'scientific temper'-objectivity, critical thinking and freedom from fear and prejudice.

Aims of Science Education, Position Paper, National Focus Group on Teaching of Science (2006) p. 11.

If you will analyze these aims in order to understand the nature of science teaching learning at school level, you will find that:

These aims are suggesting organization of science curriculum at different levels keeping in mind the cognitive levels of learners. You can recall and link levels of cognitive development suggested by Piaget here.

There is an emphasis on linkage of scientific knowledge with society i.e. scientific knowledge should be a part of society and also verified and authenticated by the learners themselves. It focuses on development of scientific process skills along with nurturing natural curiosity and aesthetic sense. Along with development of scientific attitude, equal focus is on development of universal values.

Now it will be easy for you to understand the objectives of science teaching-learning at different levels.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

1) What are the aims of science education related to values and scientific attitude?

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2.4 OBJECTIVES OF SCIENCE TEACHING-LEARNING

First aim of science education discussed in section 2.1, i.e., "*Science education should enable the learner to know the facts and principles of science and its applications, consistent with the stage of cognitive development*", guides that objectives, curriculum, methods, assessments, etc. should be different for different levels.

Main objectives of science curriculum upto secondary level is to make learners 'scientifically literate" as science is a compulsory component of the curriculum upto secondary level. Focus should be on "developing awareness among the learners about the interface of science, technology and society, sensitizing them, especially to the issues of environment and health, and enabling them to acquire practical knowledge and skills to enter the world of work." (NCF-2005).

Emphasis is more on acquiring process skills so that learners are able to deal with every changing and expanding world of science. Keeping these key points in mind, science curriculum at different level has been organized.

At the primary level, emphasis is on engaging the learners in joyfully exploring the world around and harmonizing with it. The objectives at this stage are:

- to nurture the curiosity of the child about the world (natural environment, artifacts and people),
- to have the child engage in exploratory and hands on activities to acquire the basic cognitive and psychomotor skills through observation, classification, inference, etc.;
- to emphasize design and fabrication, estimation and measurement as a prelude to development of technological and quantitative skills of later stages; and
- to develop the basic language skills: speaking, reading and writing not only for science but also through science.

At this level, Science and social science have been integrated as 'Environmental Studies'.

At the **upper primary level**, the emphasis is on engaging the learner in learning principles of science through familiar experiences, working with hands to design simple technological units and modules and continuing to learn more on environment and health through activities and surveys.

As a science teacher, you will agree that scientific concepts are learnt better if learners explore them through activities and experiments. Learners should be given opportunity to explore science in their everyday experiences. You should engage learners (preferably in groups) in meaningful investigations -particularly of the problems they perceive to be significant and important.

As a science teacher, you should encourage discussions with the teacher and peers. You can ask your learners to gather information from newspapers, knowledgeable persons in the neighbourhood, and from easily available sources and discuss about them in class with peers and teachers.

Role play, skits, cooperative learning strategies should be adopted to ensure larger participation and sharing of learning outcomes. It is advised that biographical narratives of scientists and inventors can be used. You should keep in mind that efforts should be continued for development of the process skills of science.

It is suggested that at the **secondary stage,** you should engage your learners in learning science as a composite discipline. As a science teacher at this level, you should provide them opportunity to engage in activities and analysis on issues surrounding environment and health.

As secondary stage, systematic experimentation is suggested as a tool to discover/ verify theoretical principles, and working on locally significant projects involving science and technology.

Concepts, principles and laws of science should be introduced at this level with an emphasis on comprehension and not on mere formal definitions. At this stage, those concepts, which are beyond direct experience, should also be introduced and learners should make understand that all scientific phenomena are not directly observable; science also relies on inference and interpretation.

You should use experimentation as an important tool to discover/verify theoretical principles at this stage. At this level, you should organize co-curricular activities like some small group projects on local issues and use problem-solving approach.

At the **higher secondary stage**, curriculum has adopted disciplinary approach with rigour and depth. There is strong emphasis on experiments, technology, and investigative projects. You should organize co-curricular activities at this stage by adopting a problem-solving approach on local issues involving science and technology; encouraging participation of learners through creative/ investigative projects in national science fairs and participation in science Olympiads. You should provide opportunity to your learners for participation in debates and discussions on issues at the interface of science, technology and society.

At the higher secondary stage, a transition from general science to discipline-based curriculum takes place. Physics, Chemistry and Biology are being offered as an elective subject. At this stage, the learners choose any discipline, with a purpose of pursuing their future careers in basic sciences or professional courses like medicine, engineering, technology and studying courses in applied areas of science and technology at tertiary level. Hence, at this level, the learners should be provided with sufficient conceptual background of disciplines which would eventually make them competent to meet the challenges of academic and professional courses after the higher secondary stage. At this level, focus is on:

- developing conceptual competence among the learners and making them realize and appreciate the interface of Physics, Chemistry or Biology with other disciplines;
- exposing the learners to different processes used in industrial and technological applications;
- developing process-skills and experimental, observational, manipulative, decision-making and investigatory skills in the learners;
- promoting problem-solving abilities and creative thinking to develop interest in the learners in the study of various disciplines;
- helping learners to understand the relationship between nature and matter on scientific basis, develop positive scientific attitude, and appreciate the contribution of different science disciplines towards the improvement of quality of life and human welfare;

Teaching-learning of various science subjects at the higher secondary stage enables the learners to comprehend the contemporary knowledge and develop aesthetic sensibilities and process skills. The experimental skills and process-skills

developed together with conceptual knowledge prepare the learners for more meaningful learning experiences and contribute to the significant improvement of quality of life. The learners would also appreciate the role and impact of science and technology, and their linkages with overall national development.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

2) Compare the objectives of science teaching-learning at upper primary and secondary level?

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2.5 DEVELOPING LEARNING OBJECTIVES

Discussion on aims and objectives of teaching-learning has given you a direction. Now you should focus on developing teaching-learning objectives for science classroom. We have discussed earlier that there is a shift in pedagogy in science from behaviourist to constructivist approach due to which focus is now on acquiring process skills. You have to formulate learning objectives in sync with process skills to be developed while dealing with a particular content.

In your primary/elementary teacher education programme, you must have studied about Bloom's taxonomy of instructional objectives, which was suggested in 1956. In 2001, a new taxonomy of instructional objectives has emerged which was proposed by Anderson and Krathwohl in their book "*A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives."* Anderson and Krathwohl revised the Bloom's taxonomy by removing the anomalies and giving more emphasis on verbs.

2.5.1 Anderson and Krathwohl's Taxonomy

Before starting discussion on new taxonomy, let us have a look at original Bloom's Taxonomy. In Bloom's taxonomy, there were 6 categories under cognitive domain i.e. *Knowledge*, *Comprehension, Application, Analysis, Synthesis,* and *Evaluation.* Except Application, all other 5 main categories were further divided into subcategories. It was a hierarchical structure where categories were arranged from simple to complex and concrete to abstract. It was assumed that attainment of one category is a prerequisite for next category.

KNOWLEDGE

- Knowledge of specifics
  - o Knowledge of terminology
  - o Knowledge of specific facts
- Knowledge of ways and means of dealing with specifics
  - o Knowledge of conventions
  - o Knowledge of trends and sequences
  - o Knowledge of classifications and categories
  - o Knowledge of criteria
  - o Knowledge of methodology
- Knowledge of universals and abstractions in a field
  - o Knowledge of principles and generalizations
  - o Knowledge of theories and structures

COMPREHENSION

- Translation
- Interpretation
- Extrapolation

APPLICATION

ANALYSIS

- Analysis of elements
- Analysis of relationships
- Analysis of organizational principles

SYNTHESIS

- Production of a unique communication
- Production of a plan, or proposed set of operations
- Derivation of a set of abstract relations

EVALUATION

- Evaluation in terms of internal evidence
- Judgments in terms of external criteria

Exhibit 2.1: Bloom's Taxonomy of Cognitive Domain

If you recall the objective statements, you will find that there were two major components of an objective:

a) Some subject matter content (A Noun or Noun phrase)

b) A description of what is to be done with or to that content (A verb or verb phrase)

For example, "a learner will be able to define motion." In this objective statement the noun phrase is "motion" and the verb is "define." In original taxonomy, noun and verb aspects was part of knowledge dimension.

In the revised taxonomy, first change is that noun and verb dimensions are separate. The noun is providing the basis for the Knowledge dimension and the verb is forming the basis for the Cognitive Process dimension.

The Knowledge Dimension

The new knowledge dimension contains **four categories** i.e. **factual, conceptual, procedural** and **metacognitive.** ***Metacognitive Knowledge*** involves knowledge about cognition in general as well as awareness of and knowledge about one's own cognition.

A) FACTUAL KNOWLEDGE – The basic elements that learners must know to be acquainted with a discipline or solve problems in it.

- Knowledge of terminology
- Knowledge of specific details and elements

B) CONCEPTUAL KNOWLEDGE – The interrelationships among the basic elements within a larger structure that enable them to function together.

- Knowledge of classifications and categories
- Knowledge of principles and generalizations
- Knowledge of theories, models, and structures

C) PROCEDURAL KNOWLEDGE – How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.

- Knowledge of subject-specific skills and algorithms
- Knowledge of subject-specific techniques and methods
- Knowledge of criteria for determining when to use appropriate procedures

D) METACOGNITIVE KNOWLEDGE – Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.

- Strategic knowledge
- Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
- Self-knowledge

Exhibit 2.2: The Knowledge Dimension

The Cognitive Process Dimension

In this dimension, like the original taxonomy, same number exists in the revised taxonomy also. Let us see the following table to understand the changes in revised taxonomy.

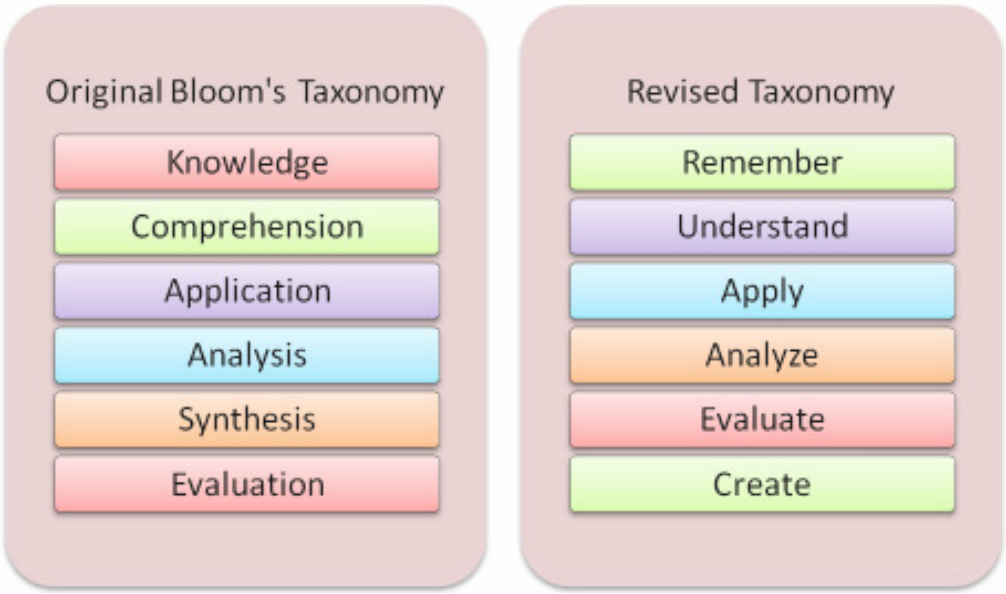
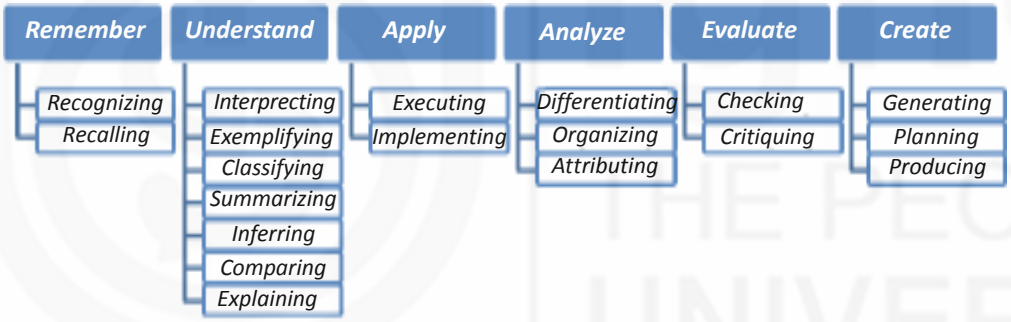


Table 2.1: Objectives in Bloom's Taxonomy and Revised Taxonomy

In above table, you can see that 'knowledge' category is renamed as 'remember', 'comprehension' is renamed as 'understand', 'Application, Analysis and Evaluation' are retained but in their verb form i.e. 'apply, analyze and evaluate'. Evaluation was last category in original taxonomy but here it is at 5th place and 'synthesis' is replaced by a new category named as 'create'.

All these 6 categories are further divided into 19 subcategories and renamed as cognitive processes. Let us have an overview of these cognitive processes.



Another very important aspect of revised taxonomy is that here every objective is represented in a "two dimensional table". The Knowledge dimension forms the vertical axis, whereas the Cognitive Process dimension forms the horizontal axis. See the following table:

The Cognitive Process Dimension

The Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
	Factual Knowledge					
	Conceptual Knowledge					
	Procedural Knowledge					
	Metacognitive Knowledge					

Let us examine following objectives:

1) Learners will be able to define the term speed.

2) Learners will be able to measure intervals of time in a wall clock.

3) Learners will be able to derive relationship between different units of speed.

Can you place all these objectives in the two dimensional table? If you start placing them, you have to analyze every objective on knowledge dimension as well as on cognitive process dimension. For example, in objective one, speed is a concept, which will fall under conceptual knowledge and defining comes under 'understand' cognitive process, hence it will fall in as below. Try to analyze other objectives also and fill the following table on your own.

The Cognitive Process Dimension

The Knowledge Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
	Factual Knowledge					
	Conceptual Knowledge	Objective 1				
	Procedural Knowledge					
	Metacognitive Knowledge					

Activity 1

Select any topic from a science textbook of class IX or X. Formulate objectives keeping in mind the nature of concept and cognitive process associated with it. Analyze your objectives by placing them in the two dimensional table.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

3) What are four major knowledge dimensions in Anderson and Krathwohl taxonomy?

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4) What are the major differences between Bloom's taxonomy and Revised Anderson and Krathwohl taxonomy of objectives in cognitive domain?

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2.5.2 How to Write Objectives

Discussion in section 2.5.1 will help to identify the cognitive processes and knowledge dimension associated with any content. As a science teacher, you have to formulate learning objectives in statement forms and also keep in mind that they should be achievable.

Mager (1997, p. 4) identified three important characteristic of an instructional objective:

- specific learning outcome (performance)
- circumstances under which learning occur (condition), and
- an element that specifies a level of proficiency (criterion).

Let us try to identify these elements with the help of few examples, which will help you to improve your objective writing.

Objective 1: Learners will be able to understand the phenomenon of heat.

Can this objective help you to tell what the learners will understand? Will it be concept or definition of heat, or heating effect? Will it be difference between hot and cold? It is not easy to answer exactly what the learners will understand and how you will assess it. The term "understand" lacks clarity and will not tell you what and how learners will tell you what they know.

Terms which are not clearly stating "action" should be avoided. Many such terms like "understand, know, appreciate, comprehend, learn, recognize" should be avoided while stating an instructional objective. Let see an improved version of objective.

Objective 1A: Learners will be able to list the hot and cold items based on their daily experiences.

If you analyze above statement in the light of three elements suggested by Mager, you will find that this objective is clearly stating the expected learner outcome, i.e. listing hot and cold items. This statement also hints at the circumstances i.e. learners' daily experiences, but this statement is lacking on third criterion i.e. element to specify the level of proficiency because one learner may list 2 items each whereas other may list 5 items. This objective statement can be refined further as:

Objective 1B: Learners will be able to list the three hot and three cold items based on their daily experiences at home.

Now this objective statement has refined second element i.e. hinting at the circumstances and included the criterion i.e. element to specify the level of proficiency by asking three items each.

Let us examine few sets learning objective statements and decide which one is better:

1A. Learners will be able to learn about soil profile.

1B. Learners will be able to level four horizons of soil in a diagram showing soil profile.

2A. Learners will be able to differentiate between amphibians and aquatic animals on the basis of their breathing organs.

2B. Learners will be able to differentiate between amphibians and aquatic animals.

3A. Learners will be able to demonstrate image formation by concave lens.

3B. Learners will be able to draw a ray-diagram showing image formation of an object placed at 2F by concave lens.

In all three sets of objectives, you will find that 1B, 2A and 3B are better written objectives. Can you identify the condition, performance and criterion elements in these objectives? Let us do an exercise.

Activity 2

Go through the objective 1B, 2A and 3B and enlist the elements in the following table:

Objective	Condition	Performance	Criterion
1B			
2A			
3B			

Sometimes you may find that all three elements are not present is an objective statement, but you should ensure that at least condition and performance elements are present in your objective statement. If you ensure presence of criterion element, it will help your assessment more effective and objective.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

5) What are three important characteristics of a learning objective statement?

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2.6 SHIFT IN PEDAGOGIC APPROACH

Behaviourism and Constructivism are often considered as two different approaches of learning, which superficially seems to be contradictory in their philosophical considerations. Behaviourism treats the learner as an organism and acting entity, on the other hand the cognitivist thoughts emphasize the importance of the *mind* in making sense of the material which it is presented. Nevertheless, it presupposes that the role of the learner is primarily *to assimilate whatever the educator presents.*

If you go through the theoretical constructs of behaviourism and constructivism, you can easily interpret that the key difference between these two approaches. Behaviourism is centred on transmission of knowledge from the instructor to the learner (passive learner and a top-down or instructor-centred approach) whereas constructivism is focused on the construction of knowledge by the learner (active learner and a bottom-up or learner-centred approach).

Constructivism in education emerged after the behaviorist movement as a welcome and refreshing view of learning that centres on the active learner within the teaching-learning process. This emphasis on the individual (within the greater social context) during instruction has drawn attention to the prior beliefs, knowledge, and skills that individuals bring with them.

When National Curriculum Framework (NCF-2005) advocated the constructivism, it highlighted following key aspects:

- **Primacy of the active learner and Learner in context**
- **Teaching should be for construction of knowledge**

These two points are like guiding principles, which have transformed all the dimensions of teaching-learning process. For a science teacher, it is important to understand the shift in various aspects of teaching-learning process, so that you can organize learning experiences in more effective manner.

2.6.1 Effect on Nature of Teaching-learning

Recall your school or college days when teaching was the core activity at school and teachers are supposed to transact the pre-identified knowledge with pre-planned teaching-learning methods to achieve certain objectives. Focus was more on teaching as it was believed that without teaching there is no learning.

Present discourse of learning has broken this jinx. Nowadays, focus is more on learning. Teaching is not a stand-alone activity rather teaching is to facilitate learning. In the constructivist perspective, learning is a process of the construction of knowledge. Teaching has occupied a facilitating role.

A shift from teacher-centred instruction to learner-centred instruction is needed to enable learners to acquire the new 21st century knowledge and skills.

In the following table, Sandholtz, Ringstaff, and Dwyer, 1997 have identified the shifts take place due to changing from a focus on teaching to a focus on learning.

Now analyze your role as a science teacher in the light of shift discussed in the above table. You will find that shift of focus from teaching to learning has created more interactive learning environment where learners can be engaged in construction of knowledge more meaningfully and actively. This has transformed the traditional role of teacher as well as perception about learner. Nowadays, learner is perceived as active learner.

Role of teacher has also changed from ***transmitter of knowledge*** to ***facilitator for knowledge creation.*** Now teachers' role is assumed as facilitator, guide, knowledge navigator and co-learner along with children. Teachers are supposed to be involved fully as a part of group of learners and facilitate by creating

conducive learning environment where children can share, construct and reflect on knowledge by their own. It does not mean that new knowledge will not be introduced by teacher. A teacher's role has changed and s/he has to create a situation where children can explore, observe, identify and create the desired knowledge with the support of teacher.

Table 2.2: Shifts in Role of Teacher and Learner

CHANGE IN ROLE OF TEACHER	
A shift from	***A shift to:***
Knowledge transmitter, primary source of information, content expert and source of all answers	Learning facilitator, collaborator, coach, mentor, knowledge navigator and co-learner
Teacher controls and directs all aspects of learning	Teacher gives learners more options and responsibilities for their own learning.
CHANGE IN ROLE OF LEARNER	
A shift from	***A shift to:***
Passive recipient of information	Active participant in the learning process
Reproducing knowledge Learning as a solitary activity	Producing and sharing knowledge, participating at times as expert Learning collaboratively with others

For creating such learning environment, you as teachers need to acquire necessary skills for planning, and designing learning situations where children can learner on their own.

2.6.2 Effect on Planning

Planning of teaching-learning has also changed with shift towards constructivist pedagogy. Classroom experiences are to be organized around learner and learner's experiences. Traditional unit planning has changed and is now uses concept mapping strategy. Idea of concept mapping was proposed by a constructivist thinker Joseph D. Novak. Novak (1982) was of the view that concept maps not only represent changes in knowledge structure of learners but also helped them "learn how to learn". Concept map provides an opportunity to link various concepts and sub-concepts and facilitate integration. Thematic approach in science teaching-learning for class VI-X adopted by NCERT is promoting use of concept mapping which is one of the major impact of NCF-2005 on science teaching-learning. Unit 5 and 6 of Block 2 is discussing it in details.

Behaviourist lesson planning approaches like Herbert and Bloom have been replaced with modern 5-E Approaches. 5-E is an inquiry based instructional model where **5-E** stands for **Engage, Explore, Explain, Elaborate,** and **Evaluate**.

In order to develop scientific process skills and using learners' experiences and knowledge for facilitating them in construction of new knowledge, 5-E is a very useful lesson planning model. Unit 5 of Block 2 will discuss about it in more details.

2.6.3 Effect on Methods and Strategies

Along with shifts in planning, a major shift has been observed in teaching-learning approach. Remember your school days, a number of competitions were the part of school activities. Classroom was filled with a competitive environment. Teachers gave lectures and gave some drill and exercises after explaining certain concepts. Parents were obsessed with competitiveness and were after their wards to make them more competitive by nature.

Under the influence of constructivist pedagogy, active learning is being promoted. Child-centred learning methods to promote construction of knowledge by the learners themselves are advised. Questioning and inquiry has become central to the classroom. Development of scientific process skills has become the objective of teaching-learning in science.

Cooperative learning strategy has brought a fresh air in the science teaching-learning environment. Focus has been shifted to cooperative learning environment. Social constructivist approach has emphasized that social contexts of learning and the knowledge is mutually built and constructed. Peer tutoring and cooperative learning become important methods of learning. You are expected to follow these methods while designing learning experiences.

In a science classroom, experiential learning, problem solving, naturalistic inquiry, investigatory projects are being promoted. All these have been discussed in detail in Unit 7 of Block 2.

2.6.4 Effect on Assessment

Earlier practices were associating term "evaluation" with examination, grading and resulting in anxiety and stress among children. Heavy load of examination and fear of failure has brought a lot of criticism for our education system. Major focus was on "assessment of learning."

Now we have shifted from "assessment of learning" to "assessment for learning". Now assessment and evaluation has become integral part of teaching learning and we are practicing a new system popularly known as ***"Continuous Comprehensive Evaluation".***

The proposed benefits of launching new system were conceptualized as it is for: (CBSE, 2010)

- reducing stress on learners so as to maximize learner's educational output;
- constantly looking over learner's performance at small intervals of course for better growth of learner;
- preventing teachers on using negative comments on learner's performance so that he/she doesn't get demoralized;
- teaching learner through various techniques and examples so that he/she understands the concept completely;
- increasing the participation of learners in the learning process so they experience everything themselves; and
- participation of learner in more and more co-curricular activities so as to recognize the abilities of an academically non-performer into other fields.

It is your responsibility as a teacher to understand this idea and act on it effectively. It has been observed that few teachers do not have epistemological understanding of CCE and they are just replacing their earlier practices with the practices under CCE. For example, monthly tests are being replaced by unit tests and trimester examination by FA-1 or FA- 2. This was not conceptualized when CCE was introduced. It's a whole new philosophy was different and focus was on learner and learning.

Different assessment strategies have been suggested for different levels. Focus is on criteria based short tests in place of formal examination. It is also being suggested to teachers that children's own self-evaluation can be the part of report card. Strategies like portfolio, worksheets, rubrics and informal observation are being promoted for practicing assessment.

We will discuss about it in detail in Unit 9: Assessment in Science. It is expected from you that you should apply the appropriate strategy and promote assessment for learning.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

6) What are shifts in role of a learner in constructivist pedagogy?

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2.7 LET US SUM UP

In this unit, discussion started with aims of science education as per National Curriculum Framework (NCF-2005). These aims help in deriving objectives of science teaching-learning at different levels. While formulating learning objectives, you should use revised taxonomy of objectives, which has been discussed in details. This revised taxonomy focuses on knowledge dimension and cognitive process dimension both. Discussion in section 2.5.2 will help you in how to write objectives in behavioural terms. It has been suggested that your statement of objective should have condition, performance and criterion elements. In last section of the unit, discussion is on pedagogical shift from behaviourist to constructivist approach and how it has affected various aspects of teaching-learning process like planning, selection of methods and strategies and assessment. These will be elaborated in various units of block 2 in more details.

2.8 UNIT END EXERCISES

1) What are the five guiding principles of national Curriculum Framework-2005? Critically analyze your secondary level science curriculum in the light of these principles.

2) What are the major differences in objectives of secondary and senior secondary science curriculum?

3) Compare Bloom's taxonomy of educational objectives with the revised Anderson and Krathwohl's taxonomy.

4) Critically analyze the effects of constructivist pedagogical approach on various aspects of science teaching-learning.

2.9 REFERENCES AND SUGGESTED READINGS

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- Krathwohl, D. R. (2002). *A Revision of Bloom's Taxonomy: An Overview*, *Theory into Practice*, 41, (4), pp. 212-218.
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- NCERT (2006). *Position paper-National Focus Group on Teaching of Science*, NCERT Publications.

2.10 ANSWERS TO CHECK YOUR PROGRESS

1) The two aims are:
   - to imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment, and
   - to cultivate 'scientific temper'-objectivity, critical thinking and freedom from fear and prejudice
2) At upper primary level, focus is on exploring science in surrounding whereas as secondary level focus has been shifted on introducing scientific concepts and phenomenon, through experimentation, exploration and observation.
3) Factual, conceptual, Procedural and Metacognitive
4) Analyze table 2.1 and answer.
5) The three important characteristics of an instructional objective are:
   - specific learning outcome (performance)
   - circumstances under which learning occur (condition), and
   - an element that specifies a level of proficiency (criterion).
6) Analyze table 2.2 and answer.

UNIT 3 PROCESS SKILLS IN SCIENCE

Structure

3.1 INTRODUCTION

While discussing about aims of science education in Unit 2, you must have noticed that now focus is on development of process skills among learners. National Curriculum Framework-2005 has also emphasized on developing these scientific skills learners so that they can construct their own understanding of science by using inquiry. Unit will discuss how learners can develop scientific attitude and scientific temper while learning science. You have to facilitate learners to develop aesthetic sense while learning science. Unit will help you in it. Curiosity initiates inquiry. How can you nurture curiosity among science learners? Unit focuses on this aspect also. While discussing nature of science in Unit 1, you have studied that science is a body of knowledge, a way of thinking (that needs development of scientific attitude), and a process of inquiry (that needs nurturing of science process skills). This unit will help you in exploring interdependence of all these aspects.

3.2 OBJECTIVES

After going through this unit, you will be able to:

- identify basic scientific process skills to be developed among learners;
- design and develop activities to help learners for developing process skills in science;
- specify your role in nurturing scientific process skills among learners;
- describe the characteristic features of scientific attitude and scientific temper;
- suggest strategies to develop scientific attitude among learners;
- facilitate learners for nurturing aesthetic sense and curiosity; and
- explore the interdependence of various aspects of nature of science.

3.3 PROCESS SKILLS IN SCIENCE

If you ask learners, what is science, you will find a common aspect in their responses i.e. science is a process of inquiry. Science involves few processes which may part of a "Scientific Method". If you look into the way science is done by scientists, you will find that there is no universal or specific scientific method. Scientists approach problems by variety of ways which have several processes common to them. These commonly used processes to conduct scientific inquiries are termed as '*Science Process skills'*.

In simple words, Science process skills are the processes which are being used by various scientists while doing science. Some common science process skills are Observing, Classifying, Communicating, Measuring, Predicting and Inferring. You may find in some examples some more advanced process skills sometimes referred as integrated skills like identifying and controlling variables, hypothesizing, interpreting data, defining operationally, experimenting and constructing models. At secondary level, your focus should remain on developing basic science process skills among learners.

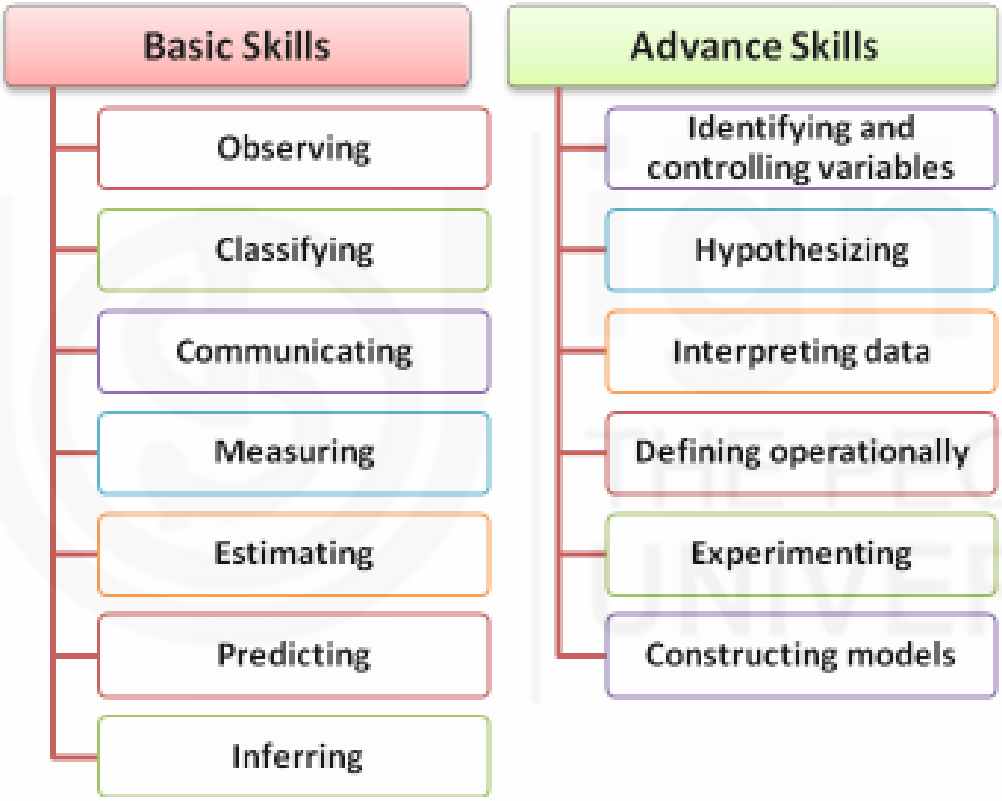


Fig.3.1: Science Process Skills

3.3.1 Basic Process Skills in Science

Let us discuss about the basic science process skills, which as a science teacher, you can develop in your learners.

Observing

Observing is the most basic process of science and creates a base for higher scientific inquiries. If you ask your learners which sense they are using while observing, many of them may reply: eyes.

You have to help them in understanding that "Observing means using our various senses to obtain information (or data) about objects or events attended". Observations are not to be limited to seeing things only. We use more than one sense organ to collect data (or information) about the objects in our daily acts. Actions like- *looking at the change of colour in litmus solution, feeling vibrations in tongs by touching it, smelling odour of resultant gas during a chemical reaction, hearing the change in pitch of sound in a musical instrument and tasting a solution to find out if it has sugar or salt in it*- involve observation using one or the other sensory organ.

You must train your learners to use all their five senses (sight, hearing, taste, smell and touch) in our science classes to help them become good observers. That means, you should give them more and more observation based activities to help them learn how to use sensory experiences to gather information about their surroundings.

Properties of different objects like **colour, size, shape, hardness, texture, lustre, sonorous and density,** etc. are all observable by using more than one sense.

Ms. Vandana, the science teacher in a secondary school in Noida, asked her learners to fill in the table, what they will observe during following activities:

Activity	**Place of Observation**	**What do you Observe?**	**Senses Involved**
Cooking			
Bird watching			
Monitoring the class			
Specimen of a fish			

When they completed the table, she asked them to define observation in their own words.

She further explained few characteristics of observation to her learners with the help of examples from this activity.

Observation has following characteristics:

- Observation focuses on "What" and "How" and not on "why".
- Observation is based on facts not opinions.
- Observation should have minimal bias i.e. it should be more objective.
- Observation is a continuous process i.e. it is not completed in one setting only.

Learners should also understand that observations may be *qualitative* or *quantitative*. For example, if you ask a learner to observe a cuboid-shaped object, she can come out with both the qualitative as well as quantitative data. She may tell you her observations about the shape, colour, material, texture (qualitative data) and dimensions i.e. length, breadth & height, volume, weight (quantitative data) of the object.

It is better if you provide a conceptual and contextual grounding for the observations. Random observations may not help learners to attend to the relevant

details of the object or event. Such as, if you tell your learners to prepare a slide of onion peel mount and ask them to observe under microscope, they may tend to report the wrinkles of peel, other distortions or air bubbles as their major observations and may overlook the typical arrangement of plant cells and its features. However, if they have already seen the diagram of onion peel in their textbooks or have read about the plant cells before this exercise, they carefully look for similar structure under microscope and locate the correct object in their slides. Helping learners develop a theoretical premise prior to observing an object or event for scientific investigation is always better. This orients learners well to attend to the relevant details of object/event under observation.

Activity 1

Design some activities through which you can help your learners in understanding that:

- Observation involves many senses.
- Observation is based on facts.

Classifying

Classification of objects (or events) is a process of imposing order on collection of objects (or events) based on similarities, differences, and interrelationships. It is good to organize our observations in ways that carry some special meaning. Learners in a secondary class have basic understanding of grouping objects into general categories. Such as, they can classify fruits and vegetables, round objects and square objects, wooden articles and plastic articles, stationery items and play material, etc. based on their everyday observations and experiences. But, they need to be given specific training for learning how to classify objects or events into scientific categories.

The more they become acquainted with scientific concepts, the better they become in classifying things/ events in appropriate categories. For example, learners tend to classify all plants together based on their general features like green colour, rooted in soil, having leaves, stems and branches, etc. similar to almost every plant. At times, they call all huge plants as "Tree" and all smaller plants including bushes and grasses as "Plants" since they group them based on height only.

As a science teacher, you know that this classification is not scientifically correct; "Plant" being the concept that includes all living organisms which produce their food through photosynthesis. At elementary level, they have learnt in their science classes about different ways of classifying plants, such as: trees, shrubs and herbs, flowering and non-flowering plants etc. at secondary level you have to introduce some higher order classifications like monocots and dicots.

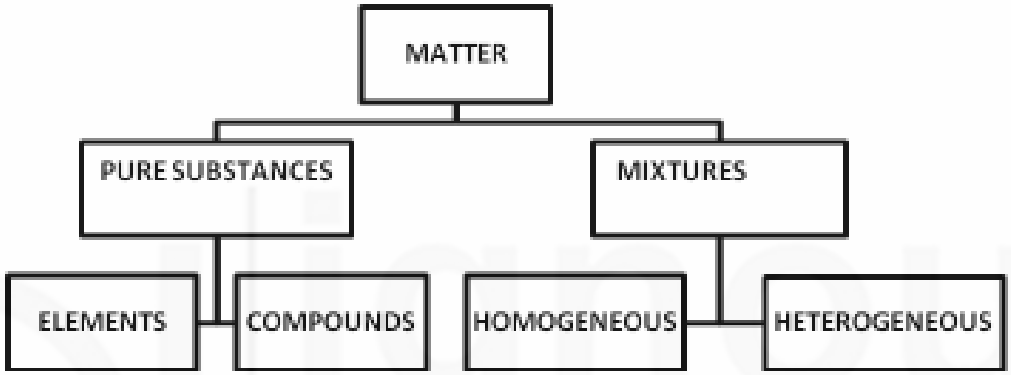
You must provide the learners with ample number of experiences to observe similarities and differences among variety of plants found in their surroundings. Learners must be able to understand the basis of every classification scheme to classify the objects into correct categories. It is usually a good idea to include classification activities together with observation activities in your day to day science classes.

It is critical to ask learners why they grouped objects the way they did to discover their thinking about the process employed. It helps them to reflect on the act and

identify the sorting errors, if any. The extent of classification depends on the depth of similarities and differences observed among a group of objects/events. You may arrive at parallel classification system or hierarchical systems of classification. Generally, learners learn parallel classification system in early grades that results into simpler categories; such as, one given below for example-

ACIDIC	BASIC
Lime Juice	Baking soda
Vinegar	Bleach
.....	.....

Gradually you can teach them to evolve hierarchical classification schemes also where they would be able to look at similarities and differences together in a given set of items. In that case, they learn that the main group starts with the most general feature and gradually proceeds towards the specific features of each subgroup it has within it. For example, look at the scheme of classification given below:



This scheme of classification of matter is hierarchical in organisation, where each subgroup has been further classified into its subordinate groups.

Activity 2

Ask your learners to classify the following materials as per the above shown scheme:

Mercury, Soil, Table salt, Sugar, Rain Water, Coffee, Carbon-dioxide, Copper, Tap water, 20 carat Gold, Iron, Glucose, Vinegar, Steel, Vegetable soup, Urea, Fountain pen ink, Blood, Gravel

Measuring is concerned with the quantification of our observations. Initially, the school learners learn to measure five basic entities while learning science- length, volume, mass (or weight), temperature and time. They should be given ample opportunities to quantify their data resulting from their observations and experimentation. You should encourage them to measure entities by using non-standard as well as standard units. Basically, the idea is to help them in adding precision to observations, classifications and communications. More of experiences should be provided for using standard scales and instruments such as rulers, meter rods, balances, graduated cylinders, calculators, stop watch, thermometers and electrical instruments, etc. to bring precision in measurements.

Gradually you can help learners to work with conversions of units, such as selecting suitable units to express or compute the data by converting one unit into another and even expressing conventional units into metric units. For

example, *converting miles to kilometers, kilometers to meters, Fahrenheit to Celsius, inches to centimeters, pounds to kilograms, grams to milligrams, liters to milliliters, hours to seconds, minutes to hours, and so on*. Further, you should note that measuring skill requires not only the precision and accuracy in handling of measuring devices, but also the ability to carry out calculations with such instruments. Learners must learn to make judgments about which instrument and units to be used and in which conditions. They must be able to understand when to use approximate and when to accurately record a data. Ability to take all such decisions is a part of measuring skills.

Activity 3

Ask learners to estimate the linear dimensions of their classroom in centimeters, meters or inches and then tell them to measure it using meter rod or inch-tape. Let the measurement be done by learners in groups and then ask them to compare their results. They might not get uniform results in each group. What could be the reasons? You should then discuss with them the reasons of varying results and the ways to ensure accuracy in measurement.

Communicating

In most generalized form, communication means sending and receiving the message through verbal or nonverbal means. People communicate in various modes such as, speaking, writing, drawing, gesturing, acting, singing, modeling, story telling, etc.

Communication in science is a specialized skill through with scientific knowledge is being shared and communicated among scientific community. In order to facilitate your learners about scientific communication, ask them to perform following activity.

Activity 4

Ask your learners to collect some descriptions about medicines given in packets of cough syrups or antibiotics, which they generally through when they purchase such medicines. Similarly they should be asked to collect some user manuals of electric equipments or mobile phone. They may be asked to collect some reports on various diagnostics laboratories or ultrasounds.

Ask them to read all these and compare on following aspects'

Are all are written in same manner?

What are the similarities and differences in these reports?

Why a description of an antibiotic is not easily understandable to them where as they read and understand a user manual well?

With such activities, you can explain following characteristics of scientific communication:

– It is systematic.

– Scientific languages are different in different areas.

– Scientific communication varies keeping in mind the reader.

All scientific communication has certain set norms, which scientists try to follow. Few are:

– All the procedures are communicated complete and in understandable language. You can find many times, that most of the processes are communicated step-by-step.

– In scientific communication, all observations are recorded and communicated with accuracy.

– Scientific communications are more in scientific languages and always avoid fancy and literary words.

– Scientific communications are not biased. They tend to be objective and accepts all explanations for testing.

You have to help your learners in understanding that science as a discipline has its own special set of symbols and modes that learners learn to become proficient in communicating better with scientific community. You know that learners verbally communicate in science classroom by talking to teacher, group discussions during some collective task, individual and personal conversations during an activity, giving oral presentation to whole class and so on. Written communication in science classroom generally happens through creative writing, making charts, graphs, posters, maps, diagrams, symbols, equations, etc. You should develop communication skills in science by encouraging learners to describe their observations as they perceive, define terms operationally, record their observations in organized form such as observation tables, equations, use of suitable charts and graphs, diagrams, and models to convey their understanding.

Inferring

Inferring is using logic to draw conclusions from what we observe and an 'inference' is an explanation to our observation about any object or event. In other words, an inference is a person's best guess about the cause of an observation. It is generally based on some evidence also. Most of the time, our inference is strongly conditioned by our past experiences and knowledge.

As a science teacher, your first task is to help your learners in differentiating between observation and inferences. Let us see one example.

Ms. Shabina, a science teacher in Central School of Vijaywada, organised a garden walk with learners and ask them to prepare a report on their visit. Here are few paragraphs what different learners have reported:

- Today we were asked to walk in garden and observe various plants. I saw various plants. Few were tall trees like mango and neems, few were shrubs like rose and few were small herbs. I also noticed that there were very few plants with fruits and flowers.

- When I walked today in garden, I noticed that most of plants and trees were without flowers and fruits. This may be due to hot summers and sun is shining brightly and there was no rain for last 2-3 months. Grass in the garden has also turned brown; it is not as green as it looks in rainy days.

- Today Shabina mam asks us to visit the garden and prepare the report. We visited the garden in small groups. In my group, there were 3 students. We all divided the task on counting types of herbs, shrubs and trees. We found that in garden, there are 4 types of herbs, 3 types of shrubs and 6 types of trees.

What do you understand by these examples? Are these simple reporting of facts or do few learners try to infer something from observation. In second example, learner explained her observation with some logic and facts. Here, she is trying to draw inference whereas in other two examples learners have reported what they observed.

You can give a variety of tasks to learners where they can practice skill of inferring.

It is necessary to help learners in making better inferences by guiding their thinking and help them learn how to make logical conclusions about an observation. For example, inferring the age of a tree from the tree rings is an activity in which inferences are drawn by calculating number of annual rings on cross-sectional pieces of a tree trunk.

Learners should realize that more than one inference can be drawn from a single set of observations. Previous knowledge and contextual experiences could bring this variation in inferences from person to person. For this, you should encourage them to discuss their observations and logically explain their inferences to each other. Also, they must gradually learn to accept that an inference can be revised with newer observations and evidences. Such as, early experiences with floating and sinking objects may lead to inference that heavy objects sink and lighter ones float. But, when they are countered with other observations and their idea of weight responsible for floating or sinking is challenged, then their inferences about the floating/sinking behaviour of objects also get modified.

Predicting

Predicting is to forecast about what a future observation will be. Predictions are based on our observations, measurements and inferences that we make about relationships among various observed variables. They are our best guesses based on the available information/data in hand. You can start with example of weather forecasts, in which meteorologists predict the weather on the basis of available information, observations, analysis and prior experiences.

It is essential to learn this skill of predicting for doing science and learners should be encouraged to predict before they test something. For example, you can ask them to predict:

- whether some object will sink or float;
- whether some object will be attracted or repelled by magnet;
- whether the bulb will glow or not in specific circuit;
- whether the seed get germinated in a specific condition or not, and so on.

You should help learners in bringing accuracy in prediction by encouraging them to make careful observations and precise measurements.

Learners' predictive thinking can be nurtured by asking them to review observed properties about an object or event and then asking them to tell the future outcomes if some sort of change is made. You should prompt them more and more for making predictions by using appropriate questioning like:

- What would happen if you place the potted plant horizontally on surface and let it grow for few days?

- What would happen if you put few drops of soap solution on a piece of cloth stained with turmeric?
- What would happen if blue vitriol is stored in an iron vessel?
- What would happen if you place an onion peel in a hypotonic solution for half an hour?

Activity 5

Design one activity each for developing following scientific process skills among your learners:

Observing Measuring Predicting

Implement the activity and prepare a report on effectiveness of the activities for developing these skills.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

1) What are basic scientific process skills?

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2) What are important characteristics of scientific communication?

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3) What is the difference between inferring and predicting?

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3.3.2 Acquiring Skills to Understand the Method and Processes of Science

Learners need to acquire basic science process skills in order to understand the method and processes of science that are used by scientists to do science. Apart from *six* basic process skills as described above, there are '*integrated skills*' as well in science- those are acquired later by learners once they have learnt using basic process skills. Basic process skills are prerequisite for integrated skills. Integrated process skills require higher order thinking and reasoning and hence they are mainly practiced in upper grades. These integrated skills include:

- Identifying and controlling variables,
- Defining operationally
- Hypothesizing,
- Experimenting,
- Interpreting data,
- Constructing models, etc.

You cannot expect learners to excel in these skills unless they have experienced or been allowed to practice them consistently. Instead you need to give them multiple opportunities to work with these skills in different content areas and contexts. In fact, you need to be patient with the learners having difficulties, since it requires to have developed formal thinking patterns among them to *experiment* in science successfully. The more you make your science classrooms process oriented, more will be the possibilities for learners to learn 'how science is done'.

Your role as a teacher is very significant where you are required to keep in mind few things while engaging learners in teaching-learning activities. For instance, you should-

- train learners for use of senses to carry out focused and objective observations in science;
- help learners learn to record their observations in both qualitative as well as quantitative manner;
- enable learners to use measuring instruments precisely and using appropriate units to present their data/ observations;
- encourage learners for communicating observations honestly without hesitation and feeling no fear while reporting deviated results;
- use appropriate questions to guide learners for making authentic observations and inferences;
- help learners to classify various objects or events and develop ability to explain the underlying criteria;
- provide opportunities to use different means of communicating data/ results of their investigations, such as charts, graphs, models, etc.;
- motivate them to share their observations and inferences with each other;
- encourage them to predict an event and then test it if it's coming out to be true or not;

- create ample opportunities for learners to use science process skills and integrating them wherever is the scope.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

3) What is the role of a teacher in developing science process skills among learners?

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3.4 DEVELOPING SCIENTIFIC ATTITUDE AND SCIENTIFIC TEMPER

Learning science does not only limit itself to acquisition of conceptual knowledge or process skills. Having a scientific bent of mind is essential for persons doing science so that they can evaluate their knowledge, actions and beliefs rationally and act logically. It is very common to see that even in today's world, many people still believe in religious superstitions and baseless rumours. People can be found believing in their lucky day, wearing lucky stone or lucky number. They attribute success or failure to their good luck or bad luck rather than practice or lack of efforts. Some superstitious practices like believing in bad omens- if cat crosses your way or if you step out during eclipse or following some so called Godmen blindly and even sacrificing innocent lives for bringing you some good luck etc., are still prevalent among several people, whereas we claim that we are living in age of science and technology. It is nothing but absence of scientific reasoning and logical thinking among such people.

In fact, it is tragic to note that many educated people including those with science background lack scientific temperament. Hence, it is considered to be an important goal to develop scientific attitude and temper among school learners so that they might develop into rational and logical beings and enlightened citizens in future. It becomes imperative for you as a science teacher to help your learners in development of critical thinking and logical reasoning through learning science.

Let us first look at the two terms mentioned here- '*Scientific Attitude*' and '*Scientific Temper*'. These terms are used interchangeably in field of science and encompass similar traits or features that are required to be developed among learners through science teaching. Attitudes can be defined as '*mental predispositions toward people, objects, subjects, events, and so on*.' (Martin, et al., 1998, pp.14). The scientific attitude is indicated by certain tendencies or mental processes in a person, which include- critical and logical thinking, curiosity, creativity and inventiveness, respect for evidence, open-mindedness, persistence, truthfulness and honesty in reporting observations, scepticism,

perseverance, objectivity, universalism and willingness to suspend judgement unless having sufficient evidences.

The term "Scientific Temper" was very prominently articulated by Pandit Jawaharlal Nehru in his famous book *Discovery of India* (1946). In this book, Nehru stated that "*The scientific approach and temper are, or should be, a way of life, a process of thinking, a method of acting and associating with our fellowmen*". He further explained that the "*scientific approach as the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on pre-conceived theory, the hard discipline of the mind — all this is necessary, not merely for the application of science but for life itself and the solution of its many problems.*"

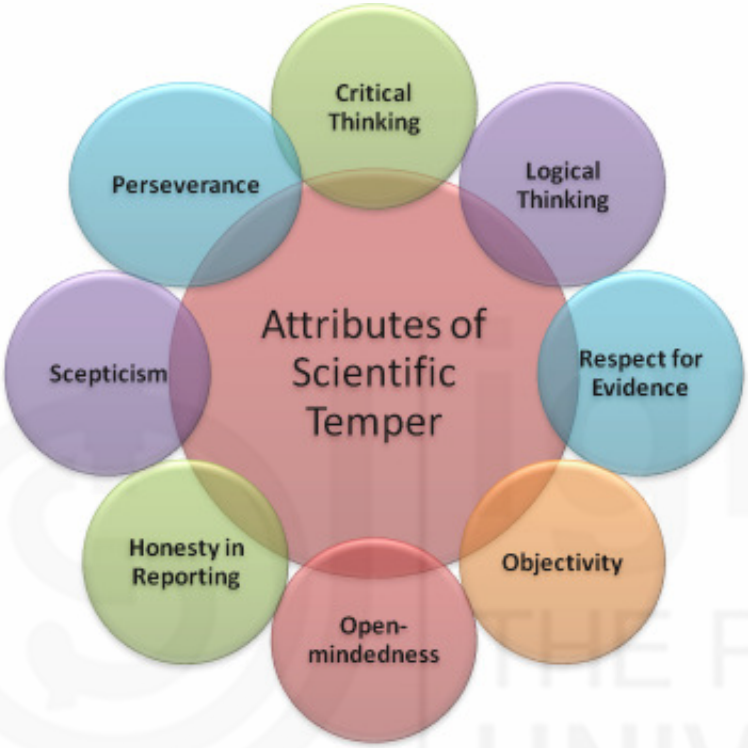

Fig. 3.2: Attributes of Scientific Temper

Let us discuss these attributes in brief; it will help you to develop a clear understanding.

Critical thinking

It is the ability to analyse our experiences and review our actions through reflecting on them. It requires an abstract thinking to reflect on our actions. We use critical thinking to evaluate whether something is adequate, correct, useful or desirable. You can nurture critical thinking among your learners by encouraging them to review their work for further improvement. You should discuss with them about the failures or mistakes in previous work. Also, discuss the alternate ways of approaching a given problem if one doesn't seem working. It is better if you ask open ended questions to encourage your learners to analyze the information and critically think on the various aspects of a given problem or experience.

Logical thinking

It requires thinking with logical reasoning. Logical thinking is the essence of having scientific temper as it makes you focus on your observations and organize them carefully through reasoning before arriving at any conclusion. You should give enough opportunities to your learners to reason out their observations. Learners start looking for patterns in terms of cause and effects before concluding once they start developing logical thinking.

Respect for evidence

Any judgment or conclusion in science should be based on suitable evidences. In case, there are not enough evidences to support a conclusion, it cannot be treated as valid scientific idea. Similarly, if there are evidences contradicting some idea, then there should be willingness to change the idea itself in the light of convincing evidences. You should help learners to collect evidences for verifying and testing their ideas about any object or event and adequately help them learn how to confront ideas with evidences.

Objectivity

This is referred to the ability of looking at things without preconceived notions, prejudices or subjective biases. Objectivity will also help in developing respect for evidences, since an objective person will only rely on unbiased evidences. If somebody sets for a scientific enquiry with some preconceived notions in mind then there are obvious chances to obtain biased results. It is better if you help your learners learn to accept any idea only after testing and verifying it against sufficient number of evidences.

Open-mindedness

An open-minded person listens to others and is willing to change her/his mind if warranted. Scientific temper demands that the person should be open-minded and flexible in her/his approach. The person is required to evaluate all observations, inferences and explanations carefully; and then accept the ones which are consistent with the evidences and offers best possible explanation of the phenomenon. Open-minded person will accept a new theoretical framework, model or paradigm over the other when she/he identifies the inconsistencies in the existing theories or the ways of approaching and explaining a phenomenon. You can help your learners to become open-minded by letting them share their viewpoints with each other and evaluate them collectively. They should be helped to show respect for best explanations and review their own conclusions if found inconsistent with the upcoming observations/evidences.

Honesty in reporting observations

Sometimes you may find learners faking their observations and manipulating their results while performing a given experiment. Have you thought about the reason for which they do so? Answer is simple, that we never emphasize on doing science experiments without fear of verifying or proving something right. Why should the learners feel pressure of coming out with ‘correct’ results while performing science experiments? Think of its impact on humanity if scientists also start doing same in their investigations. Can we really afford its outcomes? The answer is ‘No’ obviously. Then it is your duty as a science teacher to imbibe the habit of carrying out a science experiment honestly and report the actual

results. Focus should be more on processes rather than the results of inquiry. Deviations or discrepancies in the results are obvious but learners should not be penalised for it. Rather, you should help them think of the possible reasons for deviations in results obtained.

Scepticism

It is the ability to question accepted beliefs, ideas or facts prevalent in society on the basis of scientific reasoning or investigations. You should help your learners to develop this attitude of questioning widely accepted superstitions and myths in our society in the name of religion, culture, magic and so on. It is better if you give lot of space in your science classes about discussing such non-scientific ideas and beliefs to help learners develop into logical and rational thinker.

Perseverance

It is the ability to carry out something with sustained and persistent efforts. History makes it evident that lots of scientific inventions were the results of persistent efforts of scientists and for some it took their lifetime even. You must help your learners to accept their failures, learn from them and motivate for further trials.

Activity 6

Maintain a journal on "Major inventions in science". Search for the scientists and the stories behind those inventions from books, newspapers and internet resources. Reflect on the attributes of scientific attitude and temper that were evident in each story.

You must have understood that developing scientifically is basically acquiring positive scientific attitudes. Since, attitudes influence the way people respond to anything, therefore a child with a positive scientific attitude will perceive science objects, content, activities, people, etc. positively. You cannot expect your learners to develop these qualities overnight. The scientific attitude is nurtured over a period of time resulting through a consistent engagement with relevant learning activities; like performing various experiments, asking questions, reading scientific literature, and making science learning more inquiry oriented.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

4) What are the major attributes of scientific attitude?

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3.5 NURTURING AESTHETIC SENSE AND CURIOSITY

A learner of science needs to have 'aesthetic sense' that enables her/him to appreciate beauty of nature and 'curiosity' to understand natural phenomenon that further motivates her/him to reveal mysteries of nature. Aesthetic sense is concerned with the creation of something as well as ability to identify harmony, regularity and patterns in the objects or events. We learn so many laws and theories in science which indicate scientists' constant quest for searching harmony, order or regularity in nature and natural phenomenon. Be it Newton, Mendel or Darwin, everyone had that aesthetic sense and hence was able to come up with theories to explain that beauty of nature's creation.

Since scientists possess an aesthetic sense to appreciate creation of nature and natural phenomenon, therefore, they are able to identify and theorize about them. Aesthetic sense in science provides you a different lens to look at nature and natural phenomenon. Famous physicist Richard Feynman once quoted-

> *'The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree, and in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead…These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others.'*

Hence, the aesthetics and sense of wonder is significant for science learning. You should be able to infuse this ability among your learners. You must encourage them to read historical accounts of scientists and help your learners to appreciate the aesthetic sense reflected in their work. While creating science models, toys and gadgets to understand applications of science concepts, learners also derive joy and satisfaction from their work. Such opportunities should be continuously given to learners by you to nurture aesthetic sense among them.

Curiosity is another significant feature of scientists which drives them to solve mysteries of the natural world. Similarly, learners are also curious to know different things happening in their surroundings. You must have often found learners engaged in exploring their environment and questioning 'what' and 'why' about it. Those teachers, who discourage learner's questions in her/his class, will eventually suppress their natural curiosity to know about their environment. You must encourage them to put up their questions in class and help them to inquire to find out their answers themselves. You should set up the enabling and learner friendly environment in your regular classroom to nurture their curiosity. Also, you should ensure designing your teaching activities to arouse learners' curiosity in science. Organizing science fairs and science quizzes, taking them to field visits, showing science movies/documentaries, visit to science centres and exhibitions, talks with science experts and giving science literature including books, magazines and newspapers, etc. are few strategies that you can employ to nurture your learners' curiosity in science.

Activity 7

While teaching a science unit, ask your learners to evolve a list of different questions out of curiosity that come to their mind related to that unit. You can paste a chart on a wall of your classroom where each of them can write and read everyone's question. Discuss their questions after completion of the unit and encourage them to investigate for the answers through devising appropriate strategies. You can ask them to take up small investigatory projects to be done in small groups. Mentor their investigations and help them share and appreciate the findings.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

5) Why should we nurture curiosity of learners while teaching science?

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3.6 INTERDEPENDENCE OF DIFFERENT ASPECTS OF NATURE OF SCIENCE

You might remember the three major aspects of nature of science we mentioned in first unit i.e., scientific knowledge, science processes and scientific attitude. Science can't be defined in the absence of any of these aspects as they are very much interdependent on each other. Scientific knowledge is acquired through science processes and scientific attitude is necessary to deal with the content and processes of science. Similarly, learning of science helps in development of certain kind of scientific attitude and temper that helps learners to deal with their environment more logically and sensibly.

Traditional science classrooms where the focus is only on memorizing scientific laws, theories, facts and concepts don't allow learners to acquire science processes skills and don't even lead to nurture scientific temper among learners. They never learn the way a scientist would have approached the problem and inquired into it. They receive all scientific knowledge in readymade form and memorize it to clear school examinations only. Would it be called true science education that you are supposed to provide your learners? Leave aside the science concepts, would you expect those learners to critically think over everyday matters and resolve their daily life issues rationally? By the end of this unit, you must be agreeing that learning science in school should not just keep limited to 'scientific knowledge' which is anyway tentative in nature. Rather, the focus of our science teaching should be to enable learners "do" science like scientists would do and "think" like scientists would think. In short, a learner in science must acquire all of the aspects of science to understand science in its true nature.

3.7 LET US SUM UP

This unit has brought to light the different aspects of nature of science that are necessary to be developed among learners apart from the content knowledge in science. You have learnt about important objectives of teaching science that emphasize on nurturing aesthetic sense, curiosity, scientific attitude and scientific temper among learners. Development of process skills among learners is all the more necessary to help them explore and understand their own environment. All these aspects of science are important to be focused while teachings science and you need to be strategic enough to provide ample opportunities to your learners for the same.

3.8 UNIT END EXERCISES

1) Why is it more important to emphasize development of processes than the content in school science?

2) Collect news reports on recent researches taking place in field of science. Discuss few of them in your science class and help learners appreciate the way scientists have identified and approached the given problem.

3) Suggest the ways you nurture aesthetic sense and curiosity among your learners through teaching concepts of 'heredity and evolution'.

4) Plan minimum four different teaching activities for class IX learners from a unit to nurture different process skills in science. Clearly state expected skills to be nurtured through each of those activities in terms of process skill based objectives.

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3.10 ANSWERS TO CHECK YOUR PROGRESS

1) Observing, Classifying, Communicating, Measuring, Predicting and Inferring

2) It is systematic.

   Scientific languages are different in different areas.

   Scientific communication varies keeping in mind the reader.

3) Answer on the basis on your understanding of section 3.3.1

4) Attributes of scientific attitude include- critical thinking, respect for evidence, logical thinking, open mindedness, curiosity, truthfulness and honesty in reporting observations, scepticism, perseverance, objectivity, creativity and inventiveness, persistence, universalism and willingness to suspend judgment unless having sufficient evidences.

5) Curiosity leads to the questions of 'what' and 'why' in the mind of learners. In quest for searching answers to these questions, learners feel naturally motivated and interested to learn science concepts. And, we know that learners learn more easily if they are interested to learn. Science teacher must take advantage of this natural curiosity among learners about their world by engaging them in scientific processes and investigations.

UNIT 4 SCIENCE IN SCHOOL CURRICULUM

Structure

4.1 INTRODUCTION

The National Curriculum Framework (NCF)-2005 provide sample scope for the holistic development of the learners. The NCF-2005 curriculum recommends various initiatives and approaches such as activity based learning, experiential learning, collaborative learning and so on. Also, the present curricular framework keeps learners as the key player of the teaching learning process. The present day curriculum and syllabus of school education is based on the NCF-2005. Keeping the relevance of NCF-2005, apart from discussing the various aspects of NCF-2005 with regard to science curriculum, the present unit will also touch upon the developmental stages of science education and changes in science curriculum advocated by NCF-2005. As we know, science has correlation with various other subjects like mathematics, social studies, art and music etc. Thus the unit will also discuss the correlation of science with other subjects citing different examples from secondary level.

4.2 OBJECTIVES

After going through this unit, you will be able to:

- explain the developmental stages of science education;
- describe various aspects of teaching science recommended in NCF-2005;
- discuss the recent changes in science curriculum
- explain the recent trends in science curriculum;
- differentiate curriculum of science at various stages; and
- explain correlation of science with other subjects.

4.3 HISTORICAL DEVELOPMENT OF SCIENCE EDUCATION IN INDIA

The famous scientist, C.V. Raman once said, "There is only one solution for India's economic problems and that is science, more science and still more science". As we know, the progress of any country has a close relationship with the development of science. Being a science teacher trainee, you should be familiar with the development of science education. The history of science has begun with the human existence i.e. homo sapiens have utilized basic knowledge of science for their existence while Palaeolithic's tried to construct boats and houses apart from crude stone arms for hunting, which is recognised as a science activity. With the advent of human civilisation, people started to live in groups and science has influence on much of their activities. They also began to admire movement of heavenly bodies, invented mechanisms to calculate time, involved in metallurgical associated bustles, invented medicines and so on. During 600 B.C, science had grown as a theoretical entity. Excavations of Mohenjo-Daro, Harappa and Indus valley civilisations show the existence of town planning, drainage system etc.which require scientific skills and techniques.Aryabhatta, Brahmagupta, Bhsakara, Varahmihira, Atreya, Susruta, Charaka, contributed to the field of Mathematics, Medicine and Surgery. Thus we may conclude that, most of the ancient day activities involve various concepts and ideas of science.

Now we will briefly discuss the major developments in science education by categorising into three periods' such as ancient and medieval period, modern period and period after independence.

4.3.1 Science Education during Ancient and Medieval Period

In India, there were tremendous developments in the fields like mathematics, astronomy, medicine, architecture and agriculture till 600 A.D. The medicine related knowledge was adapted from Rig-Veda (assumed to be written about 4000 years back), Vaisheskia (one of the Upanishads) discusses atom and formation of world, Sankhya philosophy resembles Darwinism and the Upa-Vedas discuss about various sciences. The ancient period followed a tradition of decanting knowledge from Guru to their best disciples. The two prominent ancient universities Taxila and Nalanda were emerged as part of the effort for institutionalising education. Thereafter, the invaders from various parts of the globe like west Asia and central Asia, played major role in nurturing science education apart from Arabic, Turkish and Persian languages.

4.3.2 Science Education during Modern Period

During British, newer branch of science; ***Modern Science*** was also introduced along with study of foreign language (English). In modern science, experiments were given prominence for acquiring knowledge. But they limited science education to the elite sections of the society. Thus the country couldn't progress in scientific and technological development and secured a low position compared to western countries. During modern period, India followed the developmental process of science of western countries.

4.3.3 Science Education after Independence

The education system prevailing in the country was influenced by the England education system; but science education was not given much importance. The University Education Commission (1948), though primarily constituted for suggesting recommendations on higher education, emphasised inclusion of general science as a course in secondary level. The Secondary Education Commission (1953) advocated science subject, compulsory at both middle and secondary level and diversification of science subjects at senior secondary level. The All India Seminar on the teaching of science (1956) held at Tara Devi (Simla Hills) discussed the probable difficulties of incorporating science at senior secondary level and recommended a unique and uniform system of teaching science across the country. Under the chairmanship of late Shri Lal Bahadur Shastri, the Indian Parliamentary and Scientific Committee was set up in 1961 to study the problems of "Science Education in Schools". In the 1963, the USSR experts of UNESCO planning Mission, visited India and suggestive measures were recommended to improve Science and Mathematics education. As a result, the Department of Science Education started pilot projects in preparing new text books and associated materials. The project was experimented in 20 schools in Delhi.

Thereafter, Indian Education Commission (1964-66) recommended the following measures for the improvement of science education;

- Science and Mathematics to be made compulsory subject during first ten years of schooling
- Teaching is to be related with agriculture in rural areas and technology in urban areas
- In lower classes, science should be taught by correlating it with environment.
- At higher classes, disciplinary approach is to be implemented
- Investigatory approach of teaching is advocated
- Science corner in lower classes and laboratory-cum-lecture room in higher classes should be created

Then, based on the recommendations of Indian Education Commission, the Ministry of Education and Social Welfare set up a committee to develop curriculum for 10+2 pattern and NCERT developed a document titled "The Curriculum for the Ten-Year School –A Frame work". NCERT also prepared syllabi and textbooks whichwere adopted by CBSE. But the textbooks have invited lots of criticism for its theory dominated structure and limited scope for experimental activities. To review the same, Ishwarbhai Patel Committee was appointed in 1977. After that, based on the recommendations of Education Policy (1968), NCF-1975 was developed. Then NCF 1988 was developed based on the recommendations of Education Policy (1986) and was revised which resulted in NCF-2000. In 2005, the National Curriculum Framework was put into practice across the country. Based on NCF-2005, many state governments developed state-wise curricular framework and the same is being followed till today. In 2014, the central government appointed a committee to draft new National Educational Policy. The major recommendations of various NCFs have been discussed in the coming sections of this unit.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

1) Discuss the major developments in science education after independence?

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4.4 TEACHING OF SCIENCE AS RECOMMENDED IN NATIONAL CURRICULUM FRAMEWORK-2005

Until 1976, Indian constitution allowed state governments to take decisions on matters related to education and centre could only provide suggestions on policy issues. At the same time, the National Education Policy (1968) entrusted NCERT to develop Curriculum Framework and accordingly National Curriculum Framework-1975 was developed. In the year 1976, constitution amended to include education in concurrent list and as a result, for the first time, the country could evolve a National Policy on Education in 1986. NCERT was entrusted to develop curriculum framework. It was recommended that the curriculum should have a core component to be followed across the country. Thereafter, National Curriculum Framework for School Education (1988), Learning without Burden (1993) recommended various suggestions to improve school education. NCERT developednew National Curriculum Framework in the year 2005. The following aspects related to science education have been discussed in NCF-2005:

Criteria of Ideal Science Curriculum: What is the 'nature of science'? As we know, the physical world is explored and understood with the help of science. The facts, principles and theories of science are used to explain the physical world. It is a fact that, science is an ever-expanding knowledge sphere; many of the established universal laws are subject to change based on new observations and experiments. Even then, it is concluded that, science in general is used to explain the environmental phenomenon and physical world around us. Science is also equated to technology; technology employs the various principles of science. The relation between 'nature of science' and technology help us in formulating the 'vision of science education'. According to NCF-2005, good science education is one that is true to learner, true to life and true to science. Thus science education is intended to meet following criteria (validity) and science curriculum should adhere to it.

- *Cognitive validity* requires that the content, process, language and pedagogical practices of the curriculum are age appropriate, and within the cognitive reach of the learner (NCF-2005). For example, the basic concepts

of electromagnetic induction have to be taught before introducing the electric generator.

- *Content validity* requires that the curriculum must convey significant and correct scientific and correct information. Simplification of content, which is necessary for adapting the curriculum to the cognitive level of the learner, must not be so trivialised as to convey something basically flawed and/or meaningless(NCF-2005). What does it mean? The content transacted in the curriculum should be significant and scientifically accurate. We teach periodic table to learners just as an arrangement of elements. But it is meaningless until you expose learners to the scientific basis of ordering elements based on the atomic number (number of protons), electron configuration, chemical properties, etc. Many more logical factors contribute to the arrangement of elements in the periodic table and that must be convinced.

- *Process validity* requires that the curriculum should engage learners in acquiring the methods and processes that lead to the generation and validation of scientific knowledge and nurture the natural curiosity and creativity of the learner in science. Process validity is an important criterion since it helps the learner in 'leaning to learn' science (NCF-2005). The curriculum should engage learners in activities and experiments focusing the theory "learning to learn" and thereby developing the cognitive skills, curiosity, creativity and scientific knowledge. For example, chemical reaction is a topic to be taught by demonstrating. At the same time learners need opportunities to experience it. Thus the processes in science must be demonstrated and experimented.

- *Historical validity* requires that the science curriculum be informed by a historical perspective, enabling the learner to appreciate how the concepts of science evolve over time. It also helps the learner to view science as a social enterprise and to understand how social factors influence the development of science (NCF-2005). The knowledge that, science and scientific knowledge has historical evidence regarding its development and curriculum should emphasise it. The efforts of scientists must be appreciated by learners and they themselves have to emerge as *scientists.* For example, while you teach different branches of science, you may explain the history behind it.

- *Environmental validity* requires that science be placed in the wider context of the learners environment, local and global, enabling him/her to appreciate, the issues at the interface of science, technology and society, and equipping him/her with the requisite knowledge and skills to enter the world of work (NCF-2005). Science, technology and society are closely interrelated. The growth and progress of science and technology should benefit each other. The curricular learning experiences should relate to learners' environment. For example, learners study the concept of 'cell' but they are less concerned about faulty batteries. People throw away obsolete batteries which has harmful effects to both environment and human life as it contains harmful chemicals. Thus, while teaching science the interrelationship among various components must be taught.

- *Ethical validity* requires that the curriculum promote the values of honesty, objectivity, cooperation, and freedom from fear and prejudice, and inculcate in the learner a concern for life and preservation of the environment (NCF-2005). For example while teaching the concept 'nuclear bomb'; teachers must be able to develop qualities like empathy, sympathy, etc. in learners.

Science Curriculum at Different Stages: While developing the curriculum of various stages; the factors such as 'general aims and objectives of science education', content, pedagogical practices and mode of assessment must be considered. The various curricular activities recommended for primary, upper primary, secondary and senior secondary stages in the NCF-2005 are discussed in section 4.4.2.

Development of Inventiveness and Creativity: One of the major objectives of teaching science is to develop among the learners the spirit of inquiry and creativity. Hence, NCF-2005 recommends the following;

- Engage learners in learning activities, science fairs, experiments and projectwork, learners' science congress, co-curricular activities etc. to promote curiosity, inquisitiveness and creativity.
- Organise science and technology fairs at local, district, state and national level with coordinated effort of national and state level agencies, non-governmental organisations and teacher associations.
- Develop experimental and technological modules along with text books and develop internal assessment mechanisms for evaluation.

Textbooks: Textbooks are the core medium of transacting curriculum and thus the following points must be taken into consideration;

- Promote extensive use of textbooks among learners and teachers. This also calls for universalisation of science education.
- Incorporate diverse learning activities in the textbooks. The field experiences of teachers must be considered while writing textbooks. Also ensure the participation of teachers, state and national agencies during preparation of textbooks.

Examination System: Learners are to be assessed at various stages of learning to ensure the attainment of educational objectives. The following assessment reforms are recommended in the NCF-2005;

- Internal assessment must be practised for experiments, learning activities and technological modules even for secondary and senior secondary board examinations.
- The theoretical examination should include questions to test critical understanding, experimental skills, enquiry procedures and competency to solve problems.
- To reduce stress, learners must have freedom to attend examinations at their own choice and time and the credits could be accumulated.

Teacher Empowerment: The future teachers are trained and shaped at the teacher education institutions. The quality of learner-teachers depends on the quality of teachers by whom they are trained. In such a scenario, the following are recommended for teacher education institutions;

- The teacher training practices requires a complete overhaul in training programme, pedagogic practices, curriculum and training of science teachers. Future science teachers must be oriented and given training in skills and competencies in science teaching.
- Teachers who have school teaching experience must be appointed as science teacher educators. Recruitment modalities must be modified to appoint qualified teachers.
- Qualified and trained teachers must be attracted and appointed at various levels of schooling. Academic autonomy could be provided to maintain the quality of teaching.
- Implement measures to practice peer interaction among teachers and exchange of teachers within and outside schools may be promoted.
- Discourage the practice of entrusting teachers with extracurricular duties, reward and honour best practising teachers with incentives and promotional schemes.

Equity: The disparity among poor and rich, caste inequalities, regional indifferences, etc. hinders the economic and cultural development. Each school subject should prepare learners fight against such anomalies. The following are suggested to maintain the equality and removal of discrepancies;

- Use science education as an instrument to build awareness and removal of caste issues, religious problems, gender divide, etc. This removes social – economic divide and bring in social transformation among people.
- Even though curriculum is context focused, it should provide scope to respect individual and diverse life styles.
- Implement suitable measures to sensitise teachers for a gender fair science education, both at pre-service and in-service stages.
- Use of ICT as a medium to promote science education and to reach the weaker and rural sections of the society thereby eliminating social divide of deprivation of education.

Activities

1) Compare the NCF-2000 and NCF-2005 and critically analyse the recommendations made on science teaching.
2) Collect views of your fellow teacher trainees about NCF-2005 and prepare a report.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

2) "According to NCF 2005, the science curriculum should meet different criteria (validity)". Discuss the statement.

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3) Discuss the recommendations of NCF-2005 made on teacher empowerment.

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4.4.1 Recent Trend in Science Curriculum

Today scienceis taught as 'integrated science' in secondary classes while at senior secondary level learners study science as disciplines such as physics, chemistry and biology. The syllabus at secondary level focus on themes like Food materials, The world of living , Moving Things, People and Ideas and Natural resources, etc. But disciplinary approach is followed at senior secondary classes. As we know, a variety of changes has been brought in school curriculum from time to time as result of various education policies and curricular frame works such as National Education Policy (1975), National Curriculum Framework (1975), National Policy on Education (1986), National Curriculum Framework (1988), and National Curriculum Framework (2000 and 2005).

The NCF of 1975 recommended 10+2 pattern of school education with general education of 10 years; science as a core subject as activity based integrated subject till class X. The National Curriculum for Elementary and Secondary Education (NCESE) of 1988 also suggested general science as a core subject up to class X. The curriculum should be 'learner centred' aiming to develop abilities in cognitive, affective and psychomotor domain of the learners. The learning of science at secondary stage should help learners to develop the skills of problem solving and decision making along with comprehension of key concepts across various disciplines. The National Curriculum Framework for school Education (NCFSE), 2000 recommended teaching of science and technology in classes VI to X as single disciplines and disciplinary approach in senior secondary level. NCFSE also suggested to include 'technology; in science courses as technology has influence on life in varied ways.

The committee constituted to outline National Curriculum Framework-2005 remarks on science education "looking at the complex scenario of education in India, three issues stand out unmistakably. First, science education is still far from achieving the goal of equity enshrined in our constitution. Second, science education in India, even at its best, develops competence but does not encourage inventiveness and creativity. Third, the overpowering examination system is basic to most, if not all, the fundamental problems of science education in India". The committee recommended various suggestions on science curriculum, pedagogy, content, examination, teacher training processes, etc. NCF-2005 reinstates the recommendations of NPE 1986; curriculum should have a common core and other components that are flexible. The following are the recommendations related to science education outlined in the NCF-2005.

Constructivist Approach of Learning: The NCF-2005 places learners at the centre of teaching –learning process. NCF remarks, the knowledge construction is an evolving process and learners constantly develop knowledge by actively participating and utilizing his/her previous experiences. The active participation of the learners in the teaching-learning process is a prerequisite for the construction of knowledge. Thus the 'constructivist approach' of learning is emphasised by NCF-2005.

Learner Centred Syllabus: The information load in syllabus is reduced by considering the report 'Learning without Burden' and thus age appropriate concepts are included in the syllabus. 'Learner Centred' syllabus has been recommended that would enable learners to develop problem solving skills, curiosity, inquisitiveness, etc. Food and Nutrition, Health, Population, Agriculture, Environmental Protection forms the essential components of syllabus. The Learner is expected to develop skills in **process of science** rather than acquaintance with **content of science**.

Pedagogical Shift: Pedagogy deals with strategies and practices concerning organisation of teaching learning activities in a classroom. The NCF-2005 has recommended extensive changes in various pedagogical aspects. Acquisition of knowledge by the learners is replaced with the approach of construction of knowledge by the learners themselves. While planning teaching-learning activities, the teacher has to consider the existing ideas of the leaner and must facilitate, guide and support learners to construct new knowledge. In such classrooms, learners are the key players and such pedagogy is called 'learner centred pedagogy'. Learner centred pedagogy is recommended by NCF-2005. Thus the teaching centred classrooms have been shifted to learner centred classrooms.

Assessment Mechanisms: The assessment of learners should include multiple assessment strategies like assessing learning activities, experiments, portfolios, presentations, project work, assignments, self-evaluation etc. The understanding and application level of learners must be assessed in place of testing the rote memorisation capabilities. The examination stress is reduced by implementing continuous and comprehensive examination (CCE). Continuous refer to assessment of learners throughout the academic year and comprehensive means assessment of overall aspects of learners including curricular, co-curricular and personality attributes.

Critical Pedagogy: NCF -2005 recommends sense of democracy in science learning through the critical pedagogy approach. Critical pedagogy is a learner centred pedagogy that considers the experience and perception of learners in the teaching-learning process thereby making learning fear free and independent for the learner. As we know, learners were considered empty slates to which the teacher was pouring factual informations. But today, the knowledge given by the teacher is critically analysed and learners construct their own knowledge. Teacher has to motivate and facilitate learners to construct knowledge in a democratic way.

Scientific Method and Scientific Inquiry: The learners must be engaged in challenging situations so as to develop the skill of inquiry and to arrive at reasonable answers employing scientific method. As learners explore answers to

problems, skills like observation, hypothesising, data collection, etc. are developed among them. Also the experience with problem solving situations helps learners to explore the world around them. Thus NCF-2005 advocates **experiential learning** in science classrooms.

Diversity, Inclusion and Planning Teaching Learning Activities: The classroom normally consists of learners having multiple skills, intelligence levels and learning styles. Also there are learners from different castes, religion, backward classes; learners with learning disabilities and learners who need special assistance. Since the classroom being diverse in nature, the teacher must plan teaching learning activities that suits the individual needs of the learners and promote meaningful learning of science

Use of Textbooks and Learning Materials: Textbooks function as an important resource for knowledge construction. Textbooks should not be loaded with factual information's rather should provide learners challenging situations to actively engage in learning processes and construction of knowledge. So textbooks and other learning materials should be used.

Different Approaches and Strategies of Learning: The NCF-2005 recommends different approaches and strategies for transaction of the curricular content to learners. The approach and strategies includes constructivist approach, 5E learning model, collaborative learning approach, problem solving approach, concept mapping, experiential learning, inquiry approach, cognitive conflict, analogy strategy, etc.

Use of Information and Communication Technology: Extensive use of various ICT resources and e-learning applications are advocated as a supplement of teaching-learning processes.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

4) Discuss the recommendations of various NCFs on science curriculum.

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5) Explain relevance of 'critical pedagogy' in learning of learners.

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Activity

3) How will you ensure the learning needs of learners in an inclusive science classroom? Suggest different approaches/strategies and prepare a report.

4.4.2 Science Curriculum at Various Stages

We have discussed the 'criteria of validity' of science curriculum, which forms the basis of curriculum of science at various stages of schooling. A brief discussion of curriculum at various stages is given below:

Primary Stage (Classes I to V): The curriculum of science at primary stage should focus on the following aspects:

- To develop cognitive and psychomotor skills by engaging and exploring nature, natural phenomena, hands-own activities, etc. This promotes the curiosity among learners as they slot in observation, classification, drawing inference, judging situation, estimation and measurements
- To help learners to internalise human values, cleanliness, honesty, cooperation, truth, hygiene, social interaction, concern for life and environment, etc. Group activities, situations to engage in activities outside classroom, opportunity to interact with nature, plays, etc. is to be promoted.
- Primary stage emphasises language skills (3RC's-Reading, Writing, Speaking) through science learning, as one of the ways. Care should be taken to transact teaching content in local language/mother tongue. The teaching learning process must be unstructured giving freedom to teacher to organise learning activities and accomplishment of overall objectives at primary stage.
- The practice of teaching science as "*Environmental Studies*" is to be continued but health education should find a prominent space. The criteria for selection of content should be meaningful, relevant and according to the interest of the learners.
- Even though teaching learning is unstructured, from class III onwards, a structured way is advocated and assessment should be continuous. Up to class II, formal assessment practice is not to be practiced. Formal periodic tests, judging based on grades are to be avoided and *no pass or fail system* is to be followed at the primary stage (Source: NCF-2005).

Upper Primary Stage (Classes V to VIII): The curriculum of science at upper primary stage should focus on the following aspects:

- Learners have opportunity to explore various elements of science and starts making sense of science in daily experiences and thus science education transit from environmental studies to elements of science and technology at the upper primary stage. Learners recognize science concepts through hands-own activities and experiments, even then not necessary to strictly follow the inductive approach of inquiry.
- The integrated approach of teaching is followed emphasising teaching science as a single subject. Emphasise teaching biographies of scientists

and inventors to inspire learners and implement experiences to acquire different process skills. Apart from textbook knowledge, create opportunities to explore, discuss, and debate environmental issues, problems of health, drug related matters, etc.

- The problems that learners sense meaningful and significant (arrived through discussions in the classrooms in the presence of teacher, communication with elders, from newspapers, etc.) must be tested and experimented apart from simple experiments and hands-own activities.
- The practice of pass and fail and no detention policy to be avoided but steps may be implemented to organise periodic assessment of learners through unit tests, term tests, etc. The weightage on annual examination should be reduced and external examination must be discarded.
- The in-service teachers should prepare question papers that assess learners' problem solving skills, data analysing skills, application of learned knowledge in various situations, solving numerical problems, etc. The tests should have both written and experimental components and open book examination may be promoted to think beyond mere recalling conceptual knowledge(Source: NCF-2005).

Secondary Stage (Classes IX and X): The curriculum of science at secondary stage should focus on the following aspects:

- Disciplinary approach(such as physics, chemistry and biology) is to be followed at secondary stage. In addition to learning definitions of science, teaching is bestowed with focus on comprehension and attainment of higher skills.
- Together with recognising theoretical knowledge, occasions are to be organised to experiment the same and project methods also may be emphasised. The curriculum should not be overloaded with teaching contents.
- The participation of learners in co-curricular activities is promoted by involving them in projects concerning local issues, environmental concerns, etc.
- The board examination should include questions that test the experimental knowledge and skills of learners(Source: NCF-2005).

Higher Secondary Stage (Classes XI to XII): The curriculum of science at higher secondary stage should focus on the following aspects:

- The option of either academic or vocational streams recommended by the NPE, 1986 may be reviewed to give chance to learners to select subjects of their interest and choice.
- The disciplinary approach of teaching may be followed with syllabus having gradual and steady flow of contents from that of secondary stage emphasising experiments, investigatory projects and technology. Nevertheless the syllabus should not be overloaded.
- The contents should be selected keeping in view the competence of learners, depth of the content, delimitations, etc. But core areas must be included. The contents must be systematically organised.

- The theoretical aspects of syllabus should emphasize conceptual understanding, problem solving skills, and critical enquiry. Opportunities must be provided to test the theories with scope to interpret, hypothesise and develop results.
- To develop awareness and impact of environmental concerns, microchemistry as a means for experimentation may be thought of as a branch of chemistry and biology. Similarly use of micro chemical techniques may be promoted.
- Learners may be encouraged to participate in co-curricular activities such as debates, discussions, mathematics and science Olympiads, informal project works, etc. But it should not be considered for formal assessment.
- Periodic assessment in curricular activities must be practiced to reduce the stress of annual examinations. The tests should contain questions to check experimental/technology skills of the learners. ICT must be widely used in whatever possible means to arouse enthusiasm and interest of learners(Source: NCF-2005).

Activities

4) Organise a debate on the topic "employing ICT for teaching-learning at higher secondary level". Prepare the list of advantages and disadvantages.

5) Conduct an action research to find the difficulties of teachers in organising classrooms based on collaborative learning approach. Prepare a report on it.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

6) Discuss the science curriculum recommended by NCF-2005 for higher secondary stage? How it is different from secondary science curriculum?

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4.5 CORRELATION OF SCIENCE WITH OTHER SUBJECTS/DISCIPLINES

As we know teaching is an art that encompasses various skills and competencies. It requires expertise of teaching skills and knowledge in other subjects. A successful teacher would be able to integrate information scattered around in various subjects. This is the base of integrated teaching. Being a teacher trainee, you must be acquainted with correlation of science with other subjects for planning effective pedagogic strategies. Let us now discuss the correlation of science.

4.5.1 Types of Correlation

Correlation of science is considered in three ways as given below:

- Correlation with daily life or environment
- Correlation within different branches of science
- Correlation with other subjects

Correlation with daily life or environment: In everyday life we utilize various objects, articles, instruments, machines and so on. Have our learners ever thought where such instruments or objects come from? If you ask a secondary learner, how does pressure cooker work or can he explain the chemical reactions of battery used in torches? Probably few may answer. The interesting fact is, we do come across different science related objects and phenomena in our daily life but learners rarely notice science behind it. For example, when a stick is put in a glass tumbler filled with water, it seems bent; the stars twinkle, etc. are the result of the particular phenomena associated with light, called refraction. The water we use is formed by combining the elements hydrogen and oxygen in a particular proportion. Thus, in many of our daily life activities/environment the presence of science is found. Thus teachers should try to transact teaching concepts by correlating science with day to day activities.

Correlation within different branches of science: Life science, zoology, botany, physics, chemistry, physiology, agriculture, geology are the different branches of science. Are these branches correlated? Can we say chemistry is not involved in physics or vice versa? Of course not! Each branch of science is related. For example, while we study osmosis (Spontaneous net movement of water across a semi permeable membrane from a region of low solute concentration to a more concentrated solution) in biology, the concept of both physics and chemistry comes in. The composition of water is studied in chemistry and movement of particles in physics. Similarly, the concept related to eye is studied with the help of lenses explained in physics. Thus it is a fact that, knowledge is not separate rather it must be taught as unified entity. It is to be kept in mind that, subjects cannot be taught in isolation but through integrated approach.

Correlation with other subjects: Teaching can be made more meaningful as you understand the correlation of science with other subjects. Here in this section, we will discuss the correlation of science with other subjects separately.

***Correlation of Science with Mathematics*:**Science and mathematics is closely related and thus we say science is incomplete without mathematics. In every branch of science mathematics occur in one way or the other in the form of numerals, symbols, formula, computations, etc. For example in physics, the topics like gravitation, motion, energy and power, heat and thermodynamics, waves and oscillations, electricity, magnetism, electric current, optics etc. employ mathematical symbols and calculations. In chemistry, structure of atoms, the laws of chemical combination, elements and compounds make use of mathematics equations, combinations and proportions. In biology and life sciences a large number topics uses the principles of mathematics. For example, the arrangement of human body structure, measurement of blood pressure and temperature involves mathematics.

***Correlation of Science with Social Studies*:** Social Studies are concerned about historical events and happenings. Each discovery has a historical background. But such stories are not paid explained in science classrooms. For example, the stories of great scientists like Galileo, Pascal, Celsius, James Watt, Faraday, Alexander Fleming, A.P.J. Abdul Kalam, C.V Raman, etc are unknown to learners. The pain and struggle that the scientists put in to discover innovative theories/ machines has to reach the learners to develop a sense of inquiry and motivation to pursue science. In geography, the evolution of different rocks and soils, movement of heavenly bodies, change of seasons, phenomena like earthquakes, landslides, eclipses, etc. are all related to science.

***Correlation of Science with Language*:** The recent NCTE norms and standards on teacher education (2014) emphasize "language across the curriculum" with the view that language has importance in each subject. The theories and principles of science, discovered after series of experiments must be expressed in a language understandable to lay man/learner. Similarly, the same must be disseminated and propagated for the betterment of the country and to develop a civilized society. Thus language finds application at many places. The expressions, symbols, formulas, theories, etc. that appear in every branch of science utilize language to express it.

***Correlation of Science with Art*:** Science and art are complimentary to each other. How is it so? A science teacher , while drawing diagrams, charts, pictures on the black board during teaching, need to know the basic skills of drawing such as orientation of the figure, measurements, color combinations and so on. At the same time, a professional artist has to have basic knowledge of length, angle, 2D and 3D images etc. to draw a picture. The same is the case with handcrafters, designers, beauticians, etc. In the case of musicians, they play attractive music with the help of principles of sound and waves learnt in physics and musical instrumentalist create beautiful rhythms applying the same principle.

Check Your Progress

Note: a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

7) What are the types of correlations in science? Describe with examples.

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8) How is science correlated with life and environment? Give examples.

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4.6 LET US SUM UP

Present unit has discussed about the stages of development of science education in India. Discussion on place of Science in our ancient literature will help you in developing a sense of pride among your learners towards rich Indian Scientific contribution. Unit has explained in details about various aspects of teaching science suggested in National Curriculum Framework- 2005. The issues of present days' science education and common perceptions about present science curricula have been discussed at length, which will help you in overcoming the shortcoming and facilitating for motivating the learners towards science. The Science curriculum at different stages will help you in understanding the linear, spiral and thematic approach, which all are adopted in designing Science curriculum. You will able to help your learners in identifying the correlation of science with other subjects also.

4.7 UNIT END EXERCISES

1) Analyse the major curricular reforms made on science curriculum since National Curriculum Framework-1975 and prepare a report of it.

2) Critically examine the recommendations of National Curriculum Framework-2005 on science curriculum of secondary stages.

3) How will you teach science by integrating it with art at higher secondary level? Describe with examples.

4) Discuss the role of teacher in classrooms that follow constructivist approach of teaching-learning.

5) How far the recommendations of NCF-2005 have been implemented? Discuss.

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4.9 ANSWERS TO CHECK YOUR PROGRESS

1) Refer to section 4.4.3

2) Cognitive validity, Content validity, Process validity, Historical validity, Environmental validity, Ethical validity- NCF-2005, mentions these criteria's must be met by the science curriculum.

3) Some of the recommendations are; teacher training practices needs to be revised, teachers having school experience must be appointed as teacher educators, qualified teachers must be appointed at school level, etc.

4) Refer to section 4.4.1

5) Critical pedagogy is learner centred pedagogy. Today learners come to class with varied experiences and knowledge. In such a scenario, teacher must consider those experiences to bring a sense of democracy in the teaching learning process. The teacher's role is to guide and motivate and thereby help learners to construct their own knowledge.

6) Refer to section 4.4.2

7) Refer to section 4.5.1

8) a) Electric kettle uses current to heat water. Current is a topic of science.

   b) Mangoes fall down due to gravity. Gravity is concept of science.