DIPLOMA IN ELEMENTARY EDUCATION
(D.El.Ed.)

Course-510

Learning Science at Upper Primary Level

Block -1
Understanding Science

NATIONAL INSTITUTE OF OPEN SCHOOLING

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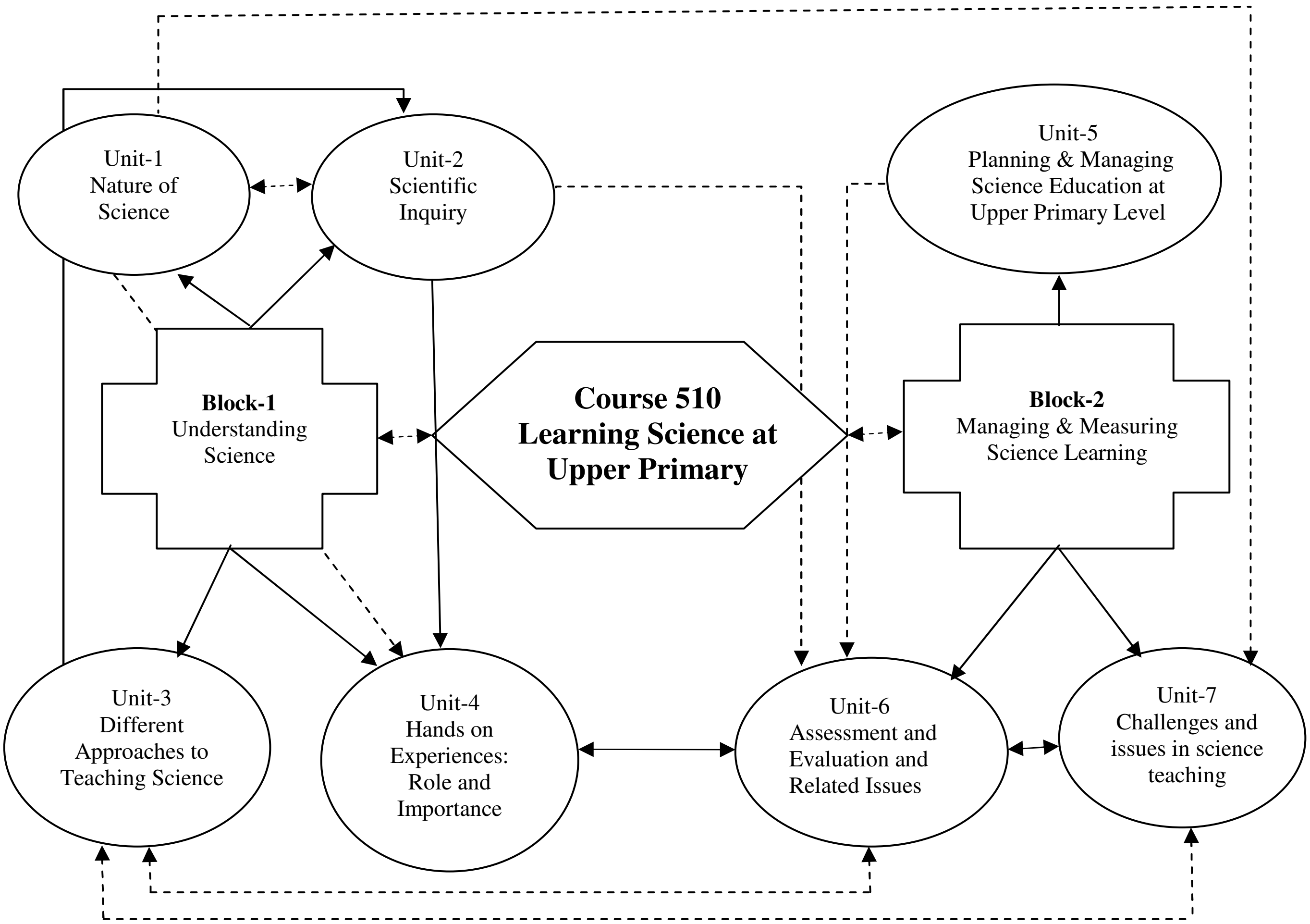
Concept Map for Course 510- "Learning Science at Upper Primary Level"



Credit points (4=3+1)

Block	Unit	Name of Unit	Theory Study hours		Practical Study hours
			Content	**Activity**	
Block-1 Understanding Science	U1	Nature of Science	6	6	1. Project - Developing and implementing material for hands on experiences for the students.
	U2	Scientific Inquiry	5	7	
	U3	Different Approaches to Teaching Science	9	9	
	U4	Hands on Experiences: Role and Importance	4	6	
Block-2 Managing & Measuring Science Learning	U5	Planning & Managing Science Education at Upper Primary Level	4	6	1. Case Study – Prepare CCE for one student and develop a follow up programme. 2. Project - Evaluation of two scenarios for deciding quality of learning.
	U6	Assessment and Evaluation and Related Issues	3	6	
	U7	Challenges and issues in Science Teaching	4	5	
		Counselling (LC)	10	-	
		Total	**45**	**45**	**30**
		Grand Total	**45+45+30=120 hrs.**		

Block 1

Understanding Science

Block Units

Unit 1 Nature of Science

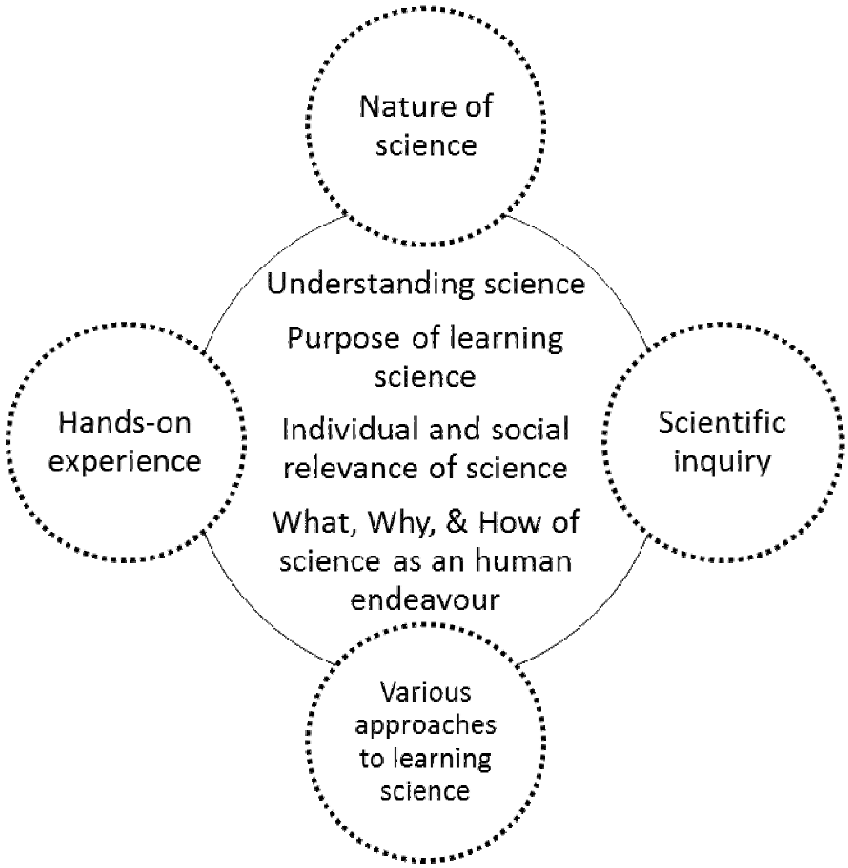
Unit 2 Scientific Inquiry

Unit 3 Different Approaches to Teaching Science

Unit 4 Hands on Experiences: Role and Importance

CONTENTS

BLOCK INTRODUCTION



This block will empower you to,

- describe nature of science and thought processes involved in science as a discipline and its relationship with the development of scientific literacy and temperament
- list the critical attributes of "scientific inquiry"
- describe the role of scientific inquiry in personal and social life
- uses the "scientific inquiry skills" in day to day life
- explain various approaches to teaching (organizing learning experiences) science
- design learning experiences for assisting learners to attain concepts and acquire skills to learn science
- relate the role and importance of hands-on experiences in learning science
- design and use various hands-on experiences to evolve a scientific discourse among learning community members

We as facilitators are responsible for empowering our pupils to take initiative in learning science. Our pupils will get interested in learning science only if we help them to understand meaning of science, its relevance in day to day life, how science as a discipline contributes towards helping human kind to lead a comfortable life. We need to help our learners to relate the importance of science as a way of life and its role in personal and social life. This will help our learners to have their own purpose of learning science.

Unit-1 will familiarize you with the **nature of science and various processes that are involved in making of science.** This will assist you to have your own rationale for teaching science. Similarly you will be able to help your pupils for their own purpose of learning science.

Unit-2 will assist you to focus on **intellectual processes involved in making of science**. Learning of this unit will assist you to design tasks for motivating learners to engage in the process of scientific inquiry.

Unit-3 will guide you for **designing learning environments using science as a medium for personality development of the learners.** This will help you to understand the necessity of having philosophical, psychological and sociological basis needed for developing lesson plans to make learning authentic. Similarly it will also help you to **promote a culture of scientific temperament** in the formal and informal class room situation.

Unit-4 will assist you to understand the role of **hands-on experiences** related in developing scientific inquiry skills. This will also help you to design and execute learning experience by using available resource.

UNIT 1   NATURE OF SCIENCE

Structure

Notes

1.0 INTRODUCTION

You will agree that the root cause of the progress of any nation is the development in Science and Technology, because Science is a dynamic and fast expanding body of knowledge. Every citizen of our country need be science literate. Therefore, it is essential to understand the nature of science by everybody in general and by teacher in particular.

This unit is divided into five sub units

- History and philosophy of science
- What is Science?
- Scientific Knowledge
- Scientific thinking
- Scientific method.

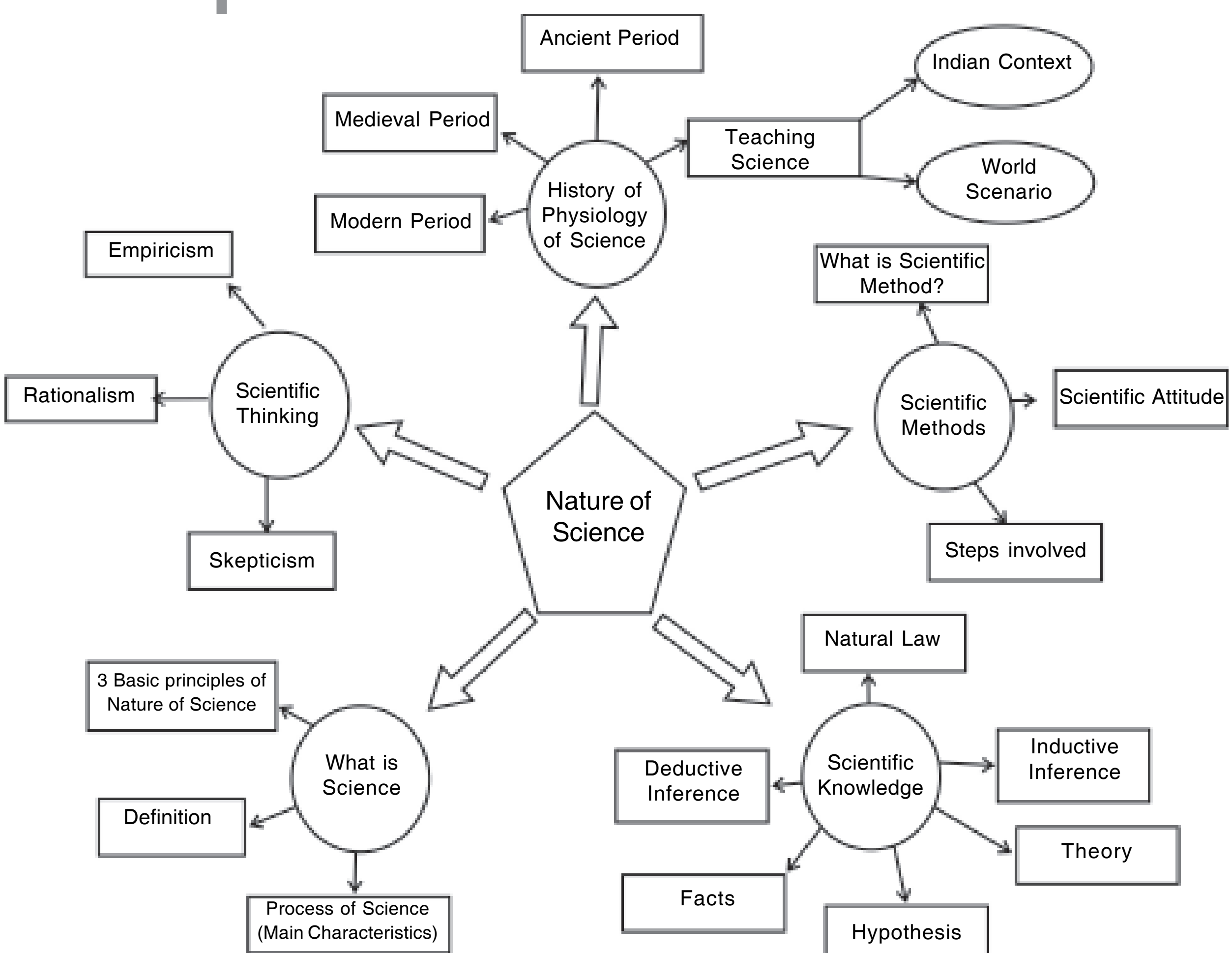


Figure 1.1 Unit concept map

This unit looks at the basic nature of the science. In the first section, we are going to see how science gets developed from ancient to modern period. Scientific thinking is a key factor in understanding the cause-effect relationship which has been discussed in the third section. Training in the method is more important than the acquiring of information. The methods of solving problems scientifically have been discussed in the fourth section. On completion of this unit you will develop an understanding of what are hypothesis, natural law, facts, and theories in science as given in figure 1.1 below. Just look at the concept map for the unit and the way different areas are related to each other and ultimately to the main theme of this unit.

1.1 LEARNING OBJECTIVES

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

- describe the historical aspect of science education and the philosophy of science
- explain the nature and process of science
- explain the process of developing scientific knowledge
- compare various scientific thinking patterns like empiricism, rationalism, and skepticism.
- describe the deductive and inductive inference.
- narrate the methodology involved in scientific enquiry.

1.2 HISTORY AND PHILOSOPHY OF SCIENCE

Today the world at large and the developing countries in particular are facing three major challenges: population rise, pollution, and poverty. Education is one of the potent instruments in the process of development, if it is properly geared for the purpose. Science education is an important component of the education system which should contribute in developing desirable knowledge skills and attitudes. What we need to achieve is to "humanize" science i.e. making science relevant to human needs. So science is a great human enterprise. Let us examine the historical development taking place in science through three major periods ancient, medieval, and modern.

1.2.1 Ancient Period

I. Indian philosophers

India made a pioneering headway in the field of Mathematics, medicine, astronomy, Agriculture, Environment, Chemistry, Aviation, Yoga and Architecture. The oldest Indian scripture Vedas were written about 7000 years ago. For our convenience we shall classify the ancient period into two eras as shown in figure 1.2 below.

Notes

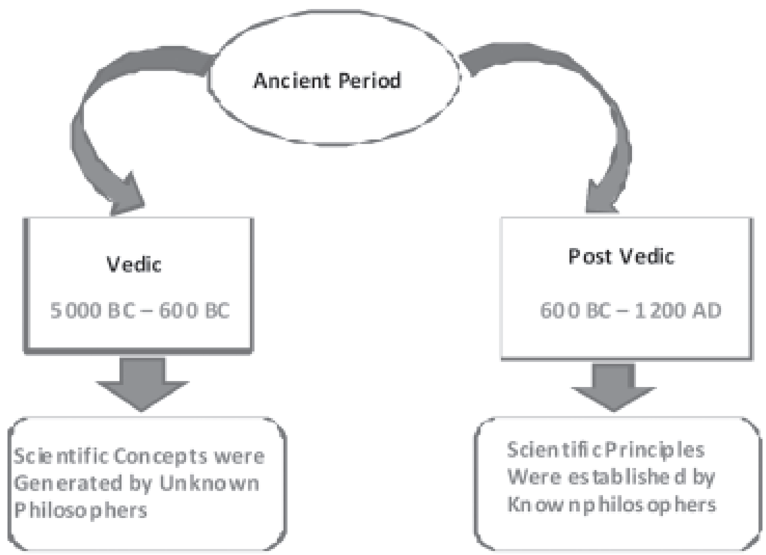


Figure 1.2 Ancient period

Four Vedas were written in 5000 BC: Rigveda , Yajurveda , Samveda and Atharvaveda. Each Veda has four parts: Samhita , Aranyak , Brahmana and Upanishad. "Kalpa" means a Sutra text. Four sutras have been described in Kalpa. (i) **rihya Sutra** which speaks about Vedic duties performed by house holders. (ii) **dharma sutra** speaks about Ethical and Moral codes. (iii) **ta Sutra** gives you the way Rituals and Vedic Sacrifice is performed (iv) **shulba Sutra** is all about Algebric calculations. Having understood the Veda and Kalpa, now let us understand the Original schools established for teaching medicine in Post-Vedic period. They are as follows. [See figure 1.3]

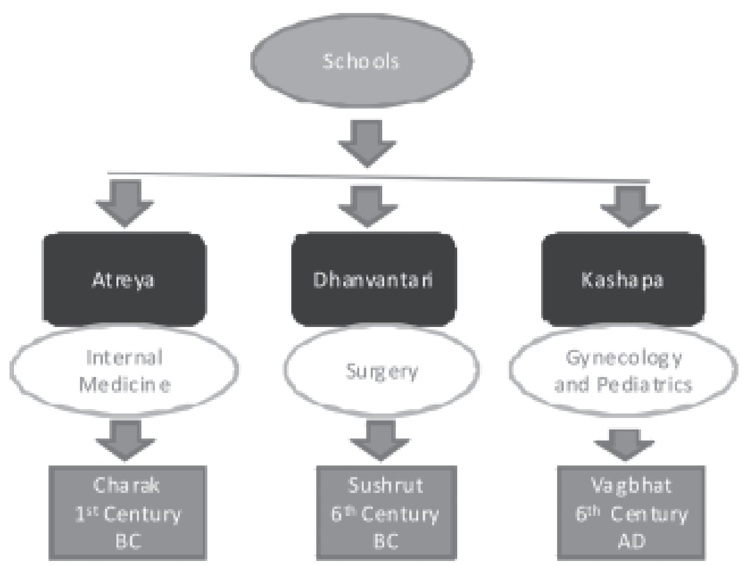


Figure 1.3 schools in Vedic period

Charak, Sushrut and Vagbhat were the experimentalists and not just philosophers. The Indian philosophers, naturalists and experimentalists in post Vedic period worked with all the three conventional research methodologies like Theoretical i.e. observations and mathematics; Experimental i.e. laboratories, instruments and equipments and descriptive i.e. survey.

Now let us see some of the important contributions, Indians made in Vedic period. Speed of light has been calculated in Rigved Samhita, Mandalam 1, Sukta 50, Mantra 4. Madhava Infinite series gave rational approximation to $\pi = 3.14159265359$.Shulba Theorem [3000 BC] is generally attributed to Pythagoras[582 BC]. Yajnavalkya [1800 BC] talks about importance of "108". The Sankhya philosophy by Kapila is like Darwinism. Ayurveda consists of six books on Surgery, anatomy, therapeutics, toxicology and local diseases.

In the post-Vedic period ancient Indian scientists made significant contributions to natural science and formulated many natural laws and scientific principles and theories. Sushruta [600 BC]in the field of Surgery , Charak [100 BC] the father of Ayurveda , Kanad [600BC]proposed the Atomic Theory , Aryabhatta [476BC]contribution to Astronomy is still recognized world wide., Varahmihir [500 AD]made significant contribution to Astronomy , Astrology , Environment and Geology., Brahmagupta [598 AD]is known as father of Algebra , Nagarjun [931 AD] established Chemistry laboratories , Patanjali [200 BC]is known throughout the world for his unique contribution to Yoga and a great mathematician Bhaskaracharya [1114 AD]for his contribution to Arithmetic and Differential calculus. His creations Sidhantshiromani and Karna- Kutuhal are known world wide.

The early universities like Takshashila [700 BC] and Nalanda could be taken as a first step in the world towards institutionalization of teaching and acquiring knowledge.

II. Western Philosophers

Western Philosophers and natural Scientists led the foundation of scientific methodology and the centre of learning was established in Greece. Here are few examples. Pythagoras a native of Greece [582 BC] brought the mathematical idea of Egyptians with a precise proof later well-known as Pythagorean theorem. Hippocrates from Greek island of Cos [460 BC] was the father of modern Medicine. Aristotle [384 BC] was an outstanding teacher and had a remarkable understanding of Scientific method as we recognize it today. Archimedes [287 BC] studied at the famous school of Mathematics in Alexandria . He was a scientist and a mathematician of extraordinary greatness – "One man and one intellect – a host in itself".

ACTIVITY - 1

Answer the following questions.

1. *Justify the importance of knowing about our ancient period?*

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2. *What were the two major eras of the Indian Ancient period?*

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3. *What are the major Ancient Indian schools?*

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4. Write the contribution of both Vedic and Post Vedic Indian and Western natural philosophers.

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1.2.2 Medieval Period

This period started from 800 AD to 1500 AD. Overall, the medieval period can be divided into the dark ages, the high middle ages, and the later middle ages [the period which preceded the renaissance]. Much was introduced in this period. Much that we have taken for granted today has roots during this period of human development.

In India, it was till the period of king Harshavardhan [606-647 AD] , India saw the best time for its art , culture and science flourishing in full bloom. The medieval period was the worst time for India because of superstition and stringent rules of caste. Most of the doctors withdrew from practice in medicine. They even shrank from touching the dead bodies and as a result of decreasing number of good physicians, public hospitals had to be closed. However in the western world it was the dawn of science. Leonardo Da Vinci [1452 AD] from Italy is considered to have been a greatest experimental scientist of his age and is acknowledged to have been one of the greatest Artists of all time, and also as a man of flying machines, hydraulics, Botany, Anatomy etc. So it was the beginning of renaissance. Nicolas Copernicus [1473 AD] a Polish astronomer , mathematician , physician and priest realized that the complex motion of planets could be explained by holding the sun still , while the earth and planets moved in orbits about that star. It took 150 years more for the world to accept this notion .Galileo Galilei [1564 AD] was possibly the best known scientist in the history of world. Galileo turned his telescope skyward for the first time in the history of science and came up with startling discoveries. He was forced upon pain of death, to publicly recant truths he had discovered and developed. Aristotelian to Galilean principles was a big paradigm shift and was a turning point in the history of science. Johannes Kepler [1571 AD] borne in Germany, discovered the laws of planetary motions. The laws were so well developed that they stood the test of two hundred years before minor inaccuracies were observed. William Harvey [1578 AD] an English Doctor discovered the circulation of blood. Harvey's seventy eight page treatise "Anatomical Dissertation concerning the motion of Heart and Blood in Animals" published in 1628 constituted a major breakthrough, after which knowledge of living functions advanced steadily and continuously.

ACTIVITY -2

You have seen that medieval period was a dark period for Science in India. What were the reasons for that to happen?

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The European scientists were responsible for the scientific revolution in the West. What was their contribution?

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1.2.3 Modern Period

The modern period brings another sharp break in the scientific thought and tradition of India with conquest of India by British. Modern science did not make significant headway in India during British period because firstly new English language made the process of its assimilation in Indian culture difficult and secondly it aroused hostility as a "British thing". This resulted in to two things. First was New knowledge could not reach the artisans and craftsmen to make an impact on their trade and second was The social and Intellectual dialogue could not take place sufficiently in large scale to make breakthrough in the scientific outlook of the people. In order to study the development of science education in India during the modern period, we have to look into the history of science in the west because whatever happened there was followed in India at a slow pace.

I. Western approach to science education

Lot of important scientific discoveries was made, theories were formulated and principles were established by the end of 18th century, however Universities neglected the teaching of Science. To name a few scientists they are as follows. Robert Boyle [1627] who discovered the behavior of the gases, Antony Van Leeuwenhoek [1632] who discovered Microorganisms , Robert Hook [1636] discovered Microscope , Isaac Newton [1642] formulated the laws of motion , Benjamin Franklin [1706] is known for his electrostatic theory, Henry Cavendish[1731] discovered Hydrogen, Joseph Priestley [1733] is known for his discovery of Oxygen, James Watt [1736] is well known for his steam engine, Edward Jenner [1749] laid the foundation of vaccinology Michael Faraday [1791] is known for his discovery of electromagnetism . It was in late 18th century number of philosophical societies was established to fulfill the social need of science education. Philosophical society of Manchester foundation in 1781 and Lunar society of Birmingham in 1766. In 1799 Rumford founded the Royal Institute of Great Britain. The intention was to teach young men on application of science to common purpose of life. Later on this society was more influenced by Sir Humphry Davy and Michael Faraday and it became the centre for research. In the early 19th century John Anderson was perhaps the first who gave the course of lectures on experimental Physics. Eventually in 1823 Glasgow Mechanics Institute was established which was raised to Technical College in 1866. In 1847 the first practical Chemistry lessons were started by Tomas Hall at City of London School. Royal commission of Education suggested that Natural science should be taught in two main branches, one comprising Physics and Chemistry and other Comparative Physiology and Natural History. In 1854 three eminent scientists urged the claim of science as an essential part of general education T H Huxley delivered an address on Educational value of Natural History of Science. John Tyndall lectured on study of Physics and Faraday stressed on cultivating a scientific outlook. "Devonshire Commission Report" was published in 1895 based on the survey of the position of Science Teaching in Secondary Schools. The publication of this report marked the beginning of the wide spread introduction of Physics and Chemistry in the curriculum of Boys' and Botany in Girls' schools .Public examinations in Science started in 1852. Most outstanding contribution in Science teaching was that of H. E. Armstrong, Professor of Chemistry at London. He advocated that all pupils should be allowed to discover things for themselves. The great World War of 1914-18 opened the eyes of general public to the importance of general science in the modern world. Sir J J Thomson appointed a committee in 1916 , as a result many advanced courses in science were added . Science Teacher's Associations were formed which created a good influence on the teachers and public. As a consequence of all this "Education Act of 1944" came into force in April 1945.

Notes

ACTIVITY -3

1. *What are the landmarks in the history of Science education?*

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2. *What are the contributions of different European societies in humanizing the science for public?*

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II. Development of science education in India

a. Uniform system of science teaching

In India the pattern of education is influenced by what happened in England. Reviews issued by the then Government of British India in the years 1877-92 gave an insight into the sorry state of science teaching. Science was never a school subject till the beginning of 20th century. Report of the Secondary Education Commission, 1953 recommended the teaching of general science as a compulsory subject in the senior secondary school. "All India Seminar on Teaching Science in Secondary School" was held at Simla Hills in 1956. It was the first of its kind touching all the related aspects like Syllabus, Equipment, Method of Examination, Teaching aids, Text books, Science clubs, Museum etc. We thought of a uniform system of science teaching in India for the first time.

b. Parliamentarians and scientists together

New ideology of bringing policy makers and Scientists was set up in 1961 under the chairmanship of late shri Lalbahadur Shastri. This committee took up in 1962 the study of the problems of "Science Education in schools". With the view to find out the relation between the policies and the decision of the centre and states and the courses offered in the schools.

c. UNESCO planning mission

In 1963, the "USSR Experts of UNESCO Planning Mission" visited India on technical assistance project. Based on the report of this Planning Mission the experimental project started in 20 schools in Delhi. "A conference of Science Education" was held during 21-23 April, 1964 under the chairmanship of Dr D S Kothari for developing effective programme of total curriculum. Indian, American, Russian and UNESCO experts participated in the conference. "The Indian Education Commission" [1964-66] was set up for planned, rapid and sustained growth in the quality education in Science and Technology." National Council of Educational Research and Training" [NCERT] was established on September 1, 1961 as an autonomous organization with its headquarter at New Delhi. The council runs National Institute of Education [NIE] which is concerned with research, instruction and evaluation and five Regional Institutes of Education. As a follow up of the Kothari Commission report, the Ministry of Education and Social welfare appointed an expert committee in 1973 to develop 10+2 pattern. "The curriculum for the Ten-year School-A framework" was published by NCERT. This pattern was implemented in 1977. Some states have now established "State Councils of Educational Research and Training" [SCERT] and "State Institutes of Science Education"[SISE] to improve the quality of Science Education in schools by way of taking up innovative programmes in science education and participate in the national science programmes. Homi Bhabha Centre for Science Education [HBCSE] was established at Mumbai in 1974. It is dedicated to Research in Science Education. It is recognized as a nodal centre for training the students for International Science Olympiad.

ACTIVITY -4

1. *How did the developments take place in Science education in India after Independence?*

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2. *What efforts were made to bring uniformity in Science education in India?*

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3. *What steps have been taken by Government of India to improve the quality of Science Education in schools?*

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1.2.4 Philosophy of Science

Philosophy of science concerns the principles and processes of scientific explanation, including both processes of confirmation and of discovery. In this we talk about assumptions, foundations, methods and implications of science. It is also concerned with the use and merit of science. Philosophy of science has historically been met with mixed response from the scientific community. Karl Popper's central question is the philosophy of science was distinguishing science from non-science. Early attempt by logical positivists grounded science in observation while non-science was non-observational. He argued that the central feature of science was that science aims at falsifiable claims i.e. claims that can be proven false, at least in principle. This gave rise to a debate regarding Evolution and Creationism. Scientists say that creationism does not meet the criteria of science and should thus not be treated on equal footing as evolution. For providing predictions about future events we often take scientific theories to offer explanations for those that occur regularly or have already occurred. Analysis has a major role to play in the philosophy of Science because it is as essential to science as it is to all rational activities. Analysis is the activity of breaking an observation or theory down into simpler concepts in order to understand it. Let us take an example. The task of describing mathematically the motion of projectile is made easier by separating out the force of Gravity, angle of projection and initial velocity. After such analysis it is possible to formulate a suitable theory of motion.

Reductionism is another concept in philosophy of science. It is a belief that all fields of study are ultimately amenable to scientific explanation. Perhaps a historical event might be explained in sociological and psychological terms, which in turn might be described in terms of human physiology, which in turn might be described in terms of Chemistry and Physics. .Daniel Dennett innovated the term Greedy reductionism. In this he claims that it is just a "Bad Science" seeking to find explanations which are appealing or eloquent, rather than those that are of use in predicting natural phenomena. . Daniel Dennett in his book "Darwin's dangerous idea" [1995] says "There is no such thing as a philosophy-free science, there is only science whose philosophical baggage is taken on border without examination".

Observations involve both Perception and Cognition

When making observations, scientists peer through telescope, study images on electronic screen, record meter reading etc. Generally on the basic level, they can agree on what they see. For example: "Thermometer showing 37.9 degree Celsius". But if these scientists have very different ideas about the theories that they supposedly explain those basic observations, they can interpret them in very different ways. Ancient scientists interpreted the rising of the sun in the morning as evidence that the sun moved. Later scientists deduce that the Earth is rotating. While some scientists may conclude that certain observations confirm a specific hypothesis, skeptic workers may yet suspect that something is wrong with the testing equipment. e.g. observation when interpreted by scientists , theories are said to be theory- laden. Observation depends on our underlying understanding of the way in which the world functions and that understanding may influence what is perceived. For example when one observes a measured increase in temperature, that observation is based on assumption about the nature of temperature and its measurement, as well as assumptions about the way the instrument used to measure the temperature functions. Such assumptions are necessary in order to obtain scientifically useful observations such as "temperature increases by two degrees".

Knowledge and belief in science

What is knowledge? There are many kinds of knowledge such as know how, know why, know that, and the like. Thus a person knows how to play the piano or how to speak French. They have "know how" when they have acquired a special kind of ability or skill. In science knowledge as "know how" is particularly important. Students need to learn to acquire skills so that they know how to perform a successful experiment, make a correct calculation, prove a theorem, solve an equation, stain a slide to view it under a microscope, etc. Knowing why is a different matter. A student knows why rainbows form after rain when they can offer an explanation of this fact by appealing to the laws of diffraction of light passing through droplets. They know why an arrow travels the distance it does before it falls to the ground, when they can explain this in terms of the laws of force and motion. Know why is linked to explanation and more generally to understanding when students can show why something happens by appealing to the laws of nature and how they work. in given circumstances. Here we will focus on a third kind of knowledge, viz., knows that. For example when does a student know that the Earth is (roughly) spherical, or knows that Pythagoras' Theorem is correct? We can all have beliefs about any subject matter; and these beliefs can be dogmatically held, or held with no good reason or in the absence of firm evidence. Moreover our beliefs can be false. So the question is: what is the difference between a person who genuinely knows, as opposed to merely believing or having an opinion? The first philosopher to propose a definition of "knows" that was Plato in his dialogue Meno. His definition of knowledge, or more precisely what it is for a person to know (say) that the Earth is round, is as follows:

First, the student must at least have a belief, for example, the belief that the Earth is round.

Second this belief must be true.

Finally the student must have the reasons, or the evidence, for the belief being true.

Ask yourself whether you merely believe that the Earth is round, or whether you know this on the basis of evidence and reason? What is this evidence? On this conception of knowledge it is important for the knower to have the evidence and simply not rely on it being available somewhere, say, being printed in some book or being in the mind of some physicist. Finally it is crucial that the belief be true, e.g., it is true that the Earth is round; if it is not true then we do not know that the Earth is round but only claim to know, or think we know when we do not. Given the above, there are two sources of scientific knowledge. The first is the knowledge we get by direct observation (in suitably controlled situations). What we observe by seeing, hearing, feeling, etc, is, on the whole, a reliable source of knowledge. Second we have knowledge when we can show the evidence, or provide the justification or the reasons, for some belief. The Ancient Greeks knew that the Earth was spherical and not flat,. But unlike astronauts out in space they could not directly observe this.

ACTIVITY -5

1. *Why do you believe that it is important to know the philosophy of Science?*

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2. *What is the significance of concepts like Analysis, Observations and Knowledge in understanding the philosophy of Science?*

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3. *Give an example of a belief that is dogmatically held.*

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4. *How Plato does define Knowledge?*

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1.3 WHAT IS SCIENCE?

Is science a text book of facts? A white lab coat, and a microscope? An Astronomer, peering through a telescope? Launching of a space shuttle? Broadcasting and telecasting sound and images through radio and television respectively? Making use of machines in household affairs?.......all these images reflect some aspects of science, but none of them provide full picture. To understand what science is, just look around you. What do you see? Paper, ball pen, telephone, computer, a family dog, sun shining through the window ...... yes science is our knowledge of all that. Everything that is in this universe, from tiny electron in an atom to the nuclear reaction that formed the fire ball of gas, which is sun.

1.3.1 Definition and General Characteristics

Science is a reliable process by which we learn about all the stuff in this universe. Science relies in testing ideas with evidence gathered from the natural world. Why is the sky blue? Why did the rain drops come downwards? Why are the roses of different colours? Are some of the innocent questions which a child may ask? It is only with the science that we can answer such questions without resorting to magical explanation. Without science modern world will never be modern at all, and we still have much to learn. The most important character of science is that it is straight forward. The aim of science is to uncover the real working of the natural world, and that requires honesty. You can not get to the truth by exaggerating results, managing numbers, selectively reporting data or interpreting evidence in a biased way. Hence scientists expect other scientists to act with integrity. Any thing that we do in science has to have objectivity. Science can be defined as "An accumulated and systematized learning in general usage restricted to natural phenomenon"

ACTIVITY-6

1. *Write your interpretation about the meaning of "science"*

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2. *List out the basic features of science?*

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1.3.2 Nature of Science

Science is both a body of knowledge and a process

In a school, science may sometimes seem like collection of isolated facts listed in text book. It is small part of the big story. It is also a process of discovery that allows us to link isolated facts into coherent and comprehensive understanding of the natural world.

Science is exciting

Scientists as well as children are motivated by the thrill of seeing or figuring out some thing that they have not done before.

Science is useful

The knowledge generated by science is powerful and reliable. It can be used to develop new technologies, treat diseases, and deal with many other problems.

Science is ongoing

Science is continually refining and expanding our horizons of knowledge of the universe. Science will never be finished. Every sunrise gets message of some invention and discoveries of knowledge

Science is a global human endeavor

Science is perceived by the people all over the world in a similar way, and they participate in the process of science which solves most of the problem of our survival

Science is a community enterprise

It is a large scale human endeavors involve a supporting community from school children to pharmaceuticals and political parties to farmers. Community level interactions inspire the scientists to spark ideas about new line of evidence, new applications, new questions and new alternative explanations. i.e. Watson and Crick got inspired by the work done by many other scientists prior to them which gave a new brilliant idea about the structure of DNA. Some people are motivated by thrill of competition offered by the community racing to unlock the sequence of Human Genome. Science is too broad for an individual on her or his own to handle. Researchers within a single narrow field like cellular biology may cover a broad spectrum of specialized topics. In this situation Division of Labor is a rule. Different researchers from different laboratories and countries share their expertise by working together. Participating in scientific community involves scrutinizing the work of others and allowing your own work to be evaluated by your peers.

1.3.3 Process of Science

Every day experience of deducing that your scooter won't start because of carbon in the spark plug, or that the centipedes in your backyard prefer a shady rock, share similarities with classical scientific discoveries like working out DNA's double helix. These activities involve making observations and analyzing evidences, and they all provide the satisfaction of finding an answer that make sense of all the facts. In fact some psychologists argue that the way individual humans learn , especially children , bears a lot of similarity to the process of science both involve making observations , considering evidence , testing ideas and holding on to those that work.

Main Characteristics of the process of science

i. Science proceeds on the assumption based on centuries of experience that the universe is not capricious.

ii. Science knowledge is based on observation of samples of matter that are accessible to public investigation in contrast to purely private inspection.

iii. Science proceeds in a piecemeal manner even though it also aims at achieving a systematic and comprehensive understanding of various aspects of nature.

iv. Science is not and probably never will be a finished enterprise and there remains very much more to be discovered about how things in the universe behave and how they are interrelated.

v. Measurement is an important feature of most branches of modern science because the formation as well as the establishment of laws are facilitated through the development of quantitative distinctions

ACTIVITY -7

Visit to vegetable market

Take a round through a vegetable market. Take a close look at the vegetables and its different types. Note down the names of different vegetables sold in the market. Classify them as fruits, leafy vegetables, flowers and roots etc.

Discuss following points with venders regarding various vegetables.

1. *Where from the vegetables are brought?*

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2. *Which mode of transport is being used?*

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3. *How many days the vegetables can be preserved in proper condition?*

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4. *Carry out the market survey in different seasons so that you will get information about vegetables which are brought in the market during the entire year.*

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Notes

1.4 SCIENTIFIC KNOWLEDGE

A group of boys went to take bath in the village pond during summer. They started playing hide and seek in water while taking bath. One of them played as thief and others started hiding themselves in water. Whosoever is noticed first declared as thief. Game continued everybody wanted not to be noticed by the designated thief, but to their surprise when they gave a deep dive in water, they could not manage to remain under water for a long even if they could control their breathing. Some could develop the trick of remaining under water by holding the rocks under water to stay longer. Those who could not, were forced to be afloat and noticed by the designated thief in the game. Now the questionarises why someone is not able to remain under water even though they could control breathing for long? Many hypotheses could be framed, such as some supernatural force under water pushes one out of water; water possesses some force which pushes one out; The fat ones stay longer because of their heavy body. The second hypotheses are discussed among peers, at home with superiors, in school with teachers.

The hypothesis discovered that water possesses upward force with exerts pressure on a body to move upward. Every object possesses mass, weight, volume, density and occupies some space to be at rest on earth. These facts give rise to the theory/ principle from the hypothesis. The hypothesis becomes instrumental to develop Archimedes principle basing on different natural laws observed and felt with liquid and solid objects by the learners. The natural laws and the derived principle are based on the facts and evidences the boys observed and experimented during bathing and at different situations.

Let us now understand the meaning of hypothesis, theory, natural law, fact, evidence etc.

"Hypothesis is an educated guess based on the observation"

1.4.1 Hypothesis

Usually Hypothesis can be supported or disproved through experimentation or more observation. Let us take a simple example. If you see no difference in the cleaning ability of various laundry detergents, you may hypothesize the "Cleaning effectiveness is not affected by which detergent you use". You can see that this hypothesis can be disproved if a stain is removed by one detergent and not another. On the other hand you cannot prove the hypothesis even if you never see a difference in the cleanliness of your clothes after trying a hundred detergents , there might be one you have not tried that could be different.

1.4.2 Theory

Theory is an accepted hypothesis. It summarizes the hypothesis or a group of hypotheses that has been supported with repeated testing. A theory is valid as long as there is no evidence to dispute it. Therefore theory can be disproved.

Scientific theory is based on a careful and rational examination of the facts. There is clear distinction between facts and Theories. Theory is not the fact itself but it interprets and correlates facts. In humanities, one finds theories whose subject matter does not concern empirical date but rather ideas. Such theories are philosophical theories as contrast with scientific theories. A philosophical theory is not necessarily scientifically tested through experiments. Here are few examples of scientific theories which are in due course of time proven wrong. Theory of spontaneous generation, by Aristotle, and Phlogiston theory by Johan Joachim Becher in 1667 are examples. Let us take an example how theories can be disproved.

Theory of spontaneous generation: Theory says that life comes from nonliving material like larva coming out of dung (gobar). This school of thought was called "Abiogenesis". It took more than 200 years for scientists to prove that life comes from life only, the school of thought called "Biogenesis". So the theory of spontaneous generation was disproved and new thought of "Biogenesis" was proved through the theory known as " Germ theory of disease causation "postulates by Louis Pasteur in 1886 .

1.4.3 Natural Law

Natural law generalizes the body of observations. It explains things, but do not describe them. These are the confirmed and verified thoughts. It is factual statement of what always happens in certain circumstances. A scientific law is a general statement that describes some general facts, or regularity of the universe. Scientific law is not a law in the sense that it must be obeyed. It is a law by virtue of the fact that no one has yet found an instance where the law does not hold.

We shall take an Example of Newton's Law of Inertia. We could use this law to predict the behavior of an object, It says that "an object at rest remains at rest and an object in motion stays in motion at the speed, unless acted upon by outside force". So in a simple language an object that is moving keeps moving unless it is acted upon by friction. Also an object that is not moving does not move unless it pulled or pushed.

1.4.4 Fact

The fact is something that really occurred. It indicates the matter under discussion deemed to be true or correct. Fact may be checked by reason , experiment , personal experience or may be argued from authority. Fact means "true" and theory means "speculation". Scientific facts are believed to be independent of the observer, no matter who performs a scientific experiment, all observers will agree on the outcome. Facts may be understood as that which makes a factual sentence true.

Example: The sentence "Jupiter is the largest planet in the solar system" is about the fact that Jupiter is the largest planet in the solar system.

Compound fact

The sentence "Ranchi is the capital city of Jharkhand" is about the following facts.

1. There is such a place as Ranchi, 2.There is such a place as Jharkhand, 3. Jharkhand has a Government, and 4.Government of Jharkhand has a power to define its capital city. 5. Jharkhand Government has chosen Ranchi to be a capital.

1.4.5 Evidence

Where does everything come from? And what does it mean? Science does give us tools to understand our universe and the laws of nature that we can observe today. Science investigates all natural phenomena. Scientists approach these investigations in all sorts of ways. Some depend on experiments, some on observations, some lead to dead ends, some to unexpected discoveries, some result in technological advances, and some cast doubt on an established theory. But despite all that diversity, the aim of science remains unchanged i.e. to build more accurate and powerful natural explanation of how the universe works. This requires testing ideas with evidence to build scientific arguments. Here the firm argument refers not to a disagreement between two people but to an evidence based line of reasoning. To make it simple we can say scientific arguments are more like the closing argument in court case than they are like the fights you may have had with your opponents. Scientific argument involves three components. One is Idea – hypothesis, second is the explanations generated by that Idea -Predictions and the third is the actual observations relevant to those expectations - the evidence. These components are always related in the same logical way.

What is our expected observation?

What do we actually observe?

Do our expectations match our observations?

Now let us see how scientist describe their arguments: "If it were a case that smoking causes lungs cancer, then we would predict that countries with high rate of smoking would have higher rates of lungs cancer" So when a scientist talks about the predicted rates of lungs cancer, he or she is really means something like "the rates that we would expect to see as an evidence if our hypothesis is correct. If the idea generates expectations that hold true then the idea is more likely to be more accurate. If our expectations do not hold true then we are less likely to accept the idea.

Example: Consider the idea that "cells are the building blocks of life." If that idea were true, we would expect to see cells in all kinds of living tissues observed under microscope, which is our expected observation. So evidence support the idea that living things are built from cells. The logic of argument is as follows.

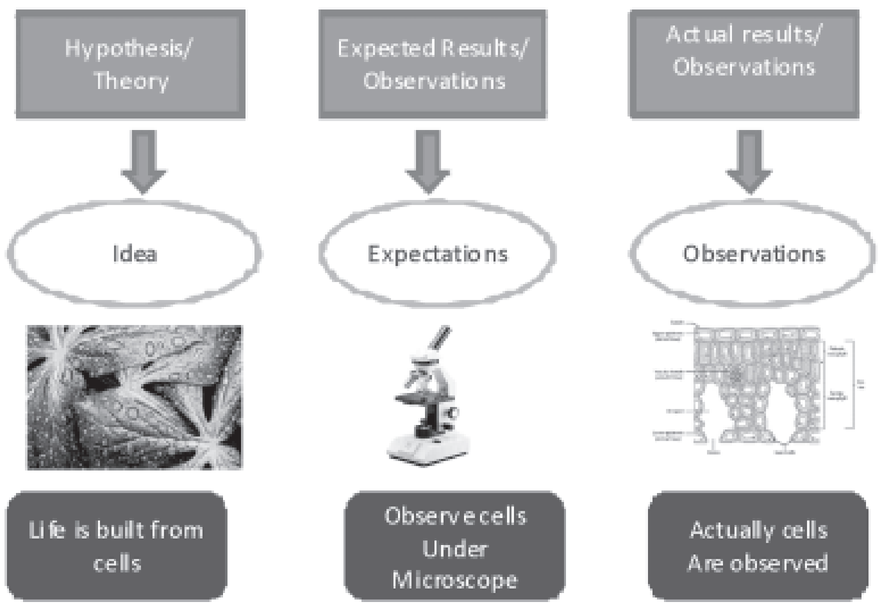

Figure 1.4 The Logic of argument

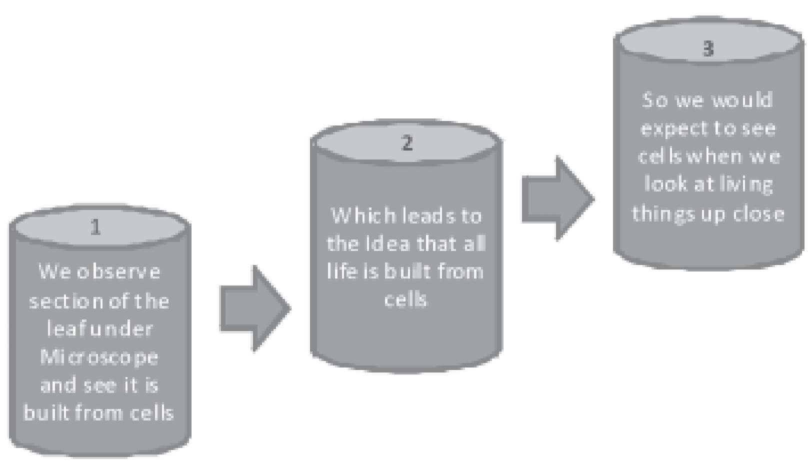

Figure 1.5 How does the argument actually resemble?

Though the structure of this argument is consistent i.e. Hypothesis .... Expectations .... Observations, its pieces may be assembled in different orders. For example, the first observations of the cells were made in 1600s, but cell theory was not postulated till 200 years later. So in this case, the evidence actually helped inspire the idea. Whether the idea came first or the evidence, the logic relating them remains the same.

Can you give an example of how the hypothesis can be disproved?

"Theory is not the fact itself but it interprets and correlates facts" How can you prove the truth of this statement?

What is the Newton's law of Inertia all about?

Why are the scientific facts independent of the observer?

How are the arguments assembled with the evidence based line of reasoning?

1.4.6 Paradigms

The paradigm is not only the current theory, but the entire world view in which it exists and all the implications which come with it. Kuhn in his book "Structure of Science" defines Paradigm shift as a scientific revolution .When enough significant anomalies have accrued against a current paradigm, the scientific discipline is thrown in to the state of crisis. During this crisis, new idea, perhaps once previously discarded, are tried. Eventually a new paradigm is formed. Paradigm shift can be most dramatic in science that appears to be stable and mature, as in Physics at the end of 19th century. At that time Physics seemed to be a discipline filling in the last few details of largely worked out system. In 1900 Lord Kelvin famously stated "There is nothing new to be discovered in Physics now. All that remains is more and more precise measurement". Five years later Albert Einstein published his paper on special relativity, which challenged the very simple set of rules laid down by Newton mechanics, which had been used to describe force and motion for over 200 years. Kuhn says "Successive transition from one paradigm to another via revolution is a usual developmental pattern of mature science." Kuhn's idea was itself revolutionary in its time, as it caused a major change in the way that academics talk about science. So this in itself was a paradigm shift in the history and sociology of science. Some of the best examples are as follows.

1. The transition in Cosmology from Ptolemaic cosmology to a Copernican one.
2. The transition in optics from Geometrical optics to physical optics.
3. Transition in mechanics from Aristotelian mechanics to classical mechanics.
4. Acceptance of theory of Biogenesis that all life comes from life as opposed to the theory of Spontaneous generation which began in 17th century and was not complete until 19th century with Pasture.

Notes

5. The transition in Newtonian Physics world view to Einsteinian Relativity world view.

6. Acceptance of Mendelein inheritance, as opposed to Darwin's Pangenesis in early 19th century.

1.4.7 Inductive Reference

This is a method; the child is led to discover truth for himself. Some concrete examples are given and with their help students are helped to arrive at certain inference. This method is a suitable method for teaching Science, Mathematics and Grammar. Let us take some examples to explain this method.

When we drop a book, it falls down.

Water flows down the slope.

A flower from a plant is attracted by the earth.

These examples lead us to generalize that all substances are attracted by earth which explains the Law of gravitation.

This method helps to develop Scientific Attitude among the students. Here knowledge is self-acquired and soon is transformed into wisdom. Inductive method is a scientific method and helps to develop scientific mindedness. Learning by doing is a basis of this method. It develops the habit of keen observation boosts your critical thinking. This method affords opportunities to you to be self-dependent and develops self-confidence. It creates a habit of intelligent hard work and makes the lessons interesting by providing challenging situations. It is a slow process. This method can be considered complete and perfect if the inferences are verified through deductive method.

1.4.8 Deductive Reference

Deductive method is reverse of Inductive method. In this method rules, generalizations and principles are provided to the students and then they are asked to verify them with the help of particular examples. We proceed from general to particular and from abstract to concrete. The teacher's work is simplified here by giving rules and asking you to verify it by application to several concrete examples. Let us take an example to understand this. You are told in advance that the boiling point of water is 100 degree Celsius and then we give them the complete procedure to perform the experiment. So now you verify the boiling point of water through the experiment. Nothing remains unknown hence there is a scope for manipulations. Your joy of discovery is lost. This method is suitable for the small children who cannot discover truths for themselves. They get ready-made material. It is time saving method because here you will not have to go through the analysis to carve out a universal truth. It is speedy process and syllabi can be covered easily. If this method is supplemented with Induction method, it would be perfect. This method has its own limitations. This method does not impart training in scientific method, and fail to develop scientific attitude in you. This method does not generate any initiative in you it rather encourages memorization of facts which are soon forgotten.

Inductive-Deductive approach

Both Inductive and Deductive approaches supplement each other. Induction should be followed by Deduction and Deduction by Induction. Therefore our approach should be Inductive cum Deductive. The combination of two methods is the best method for teaching science, Mathematics, Grammar and Physical geography.

ACTIVITY -8

Archimedes law of lever is known to you

1. *Do you know that your hand also acts as a lever? How?*

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2. *Enlist various situations in day to day life where you use different types of levers?*

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3. *Classify the levers.*

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1.5 SCIENTIFIC THINKING

Scientific thinking is a way of looking at the processes of assumptions, scientific explanation, use and merits of science. For an Empiricist knowledge arises from experience and evidence gathered specifically using senses. Skeptics do not regard the experimental results as established units. However for a rationalist, reason is the unique path to knowledge. Let us take a review of these different ways of thinking patterns.

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1.5.1 Empiricism

Empiricism addresses to the principle that knowledge arises from experience and evidence gathered specifically using senses. Leading advocates were Joann Locke, George Berkeley and David Hume. In scientific use the term Empirical refers to the gathering of data using only evidence that is observable by the senses or in some cases using calibrated scientific instruments. What Empiricist and empirical research have in common is the dependence on observable data to formulate and test theories and come to conclusion. There are many examples of empirical evidence. Darwin postulated the theory of “Natural selection” on the basis of observations only. Lamarck put forth the theory of “Use and Disuse”. The theory of” Human Carbon di-oxide emission results in global warming” is also based on evidences gathered by observations only. In fact in the Vedic period all the scientific principles were based on empirical observations. Example: Solar and Lunar eclipse, Earth moves round the sun etc. Empiricism is opposite to Rationalism in that it denies the existence of innate ideas.

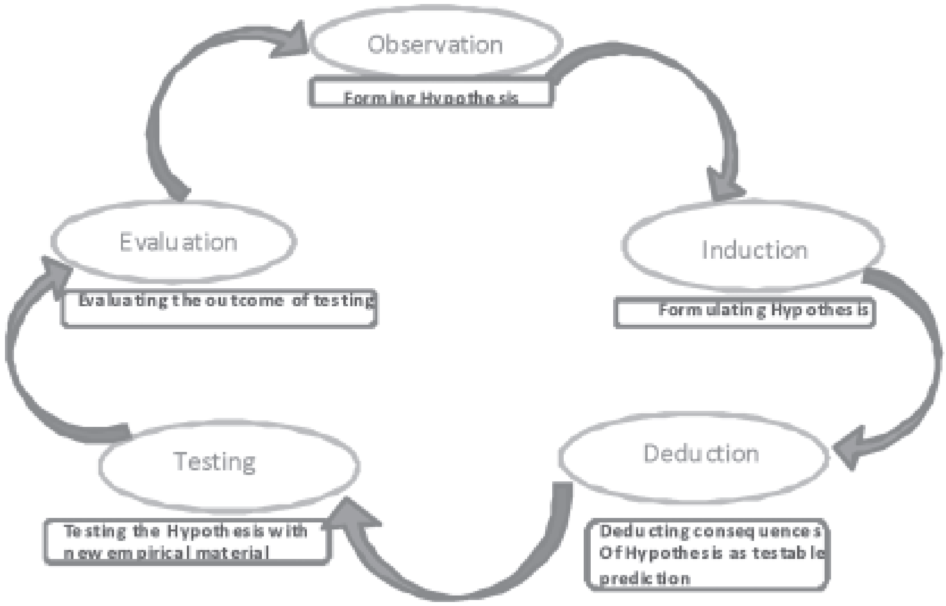

Figure 1.6 Empirical cycles by A D de Groot

1.5.2 Skepticism

Skepticism is practicing the veracity of claims lacking empirical evidence or reproducibility as a part of a methodological norm perusing “the extension of certified knowledge”. Robert K Morton asserts that all ideas must be tested and are subject to rigorous and structured community scrutiny. One must question, doubt or suspend judgments until sufficient information is available. Skeptics demand that evidence and proof be offered before conclusion can be drawn. One must thoughtfully gather evidence and be persuaded by the evidence rather than prejudice, bias or uncritical thinking.

The science that is typically written up in history books is the science of great discoveries and great theories. But there is an equally important part of science that is not glamorous, the science of skeptic. An important part of science is the requirement that new discoveries be able to be replaced by other researchers before that are accepted. This helps prevent false theories from being widely accepted. Science skepticism appears to have originated in the work of Carl Sagan. Considering the rigor of the scientific method, science itself may be thought of as unorganized form of skepticism. Scientific Skeptic attempts to evaluate claims based on verifiability and falsification and discourages accepting claims on faith or anecdotal evidence. Skeptic does not assert that unusual claims should be automatically rejected out of hand on a priori grounds – rather they argue that claims of paranormal or anomalous phenomena should be critically examined and that extraordinary claims would require extraordinary evidence in their favour before they could be accepted as being valid. Skepticism is a part of the scientific method, for instance an experimental result is not regarded as established unit, and it can be shown to be repeatable independently.

Here is an example: Galileo verified the Aristotelian principle very critically and made a claim that Light and the heavy objects falling from the same distance reach the earth surface at the same time. Gravity pulls both heavy and light objects with the same force. According to Aristotelian principle scientists use to believe the wrong concept that heavy object falls first and then the lighter one. Galileo was the great skeptic of his time.

Pseudo skepticism

There are some members of the skeptics' group who clearly believe that they know the right answer prior to inquiry. They appear not to be interested in weighing alternatives, investigating strange claims or trying out experiments or alter the state of their mind, but only in promoting their own particular belief structure.

1.5.3 Rationalism

It is a type of thinking in which the criterion of the truth is not sensory but intellectual and deductive [Bourke]. Reason is the unique path to knowledge. Rationalism is often contrasted with empiricism. Taken very broadly philosopher can be both rationalist and empiricist [Lacey]. Socrates [470-399 BC] firmly believed that before human can understand the world, they first need to understand themselves and the only to accomplish that is with rational thought. To understand what this means, one must first appreciate the Greek understanding of the world. Man is composed of two parts. That is an irrational part, which is the emotions and desires, and the rational part, which is our true self. In our every day experience, the irrational soul is drawn in to the physical body by its desire and merged with it, so that our perception of the world is limited to that delivered by the physical senses. The rational soul is beyond our awareness. The task of philosophers is to refine and eventually extract the irrational

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soul from its bondage, hence the need for moral development and then to connect with the rational soul in order to become a complete person. He did not publish or write any of his thoughts. He would usually start by asking theatrical seemingly answerable question, to which the other would give an answer. He then continues to ask questions, until all conflicts were resolved, or until the other could do nothing else but admit to not knowing the answer. Socrates did not claim to know the answer, but did not impair his ability to critically and rationally approach problems. His goal was to show that, ultimately our intellectual approach to the world is flawed and we must transcend this to obtain true knowledge of what things are. Rene Descartes [1596-1650] argued that dreams cannot provide person with knowledge. Reason alone determines knowledge. Immanuel Kant [1724-1804] to the empiricists argued that while it is correct that experience is fundamentally necessary for human knowledge, reason is necessary for processing that experience into coherent thought. A self-evident proposition has the strange property of being such that, on merely understanding what it says, and without any further checking or special evidence of any kind, we can just intellectually "see" that it is true. Examples might be such propositions as:

*Any surface that is red is colored.

*If A is greater than B, and B is greater than C, then A is greater than C.

The claim is that, once these statements are understood, it takes no further sense experience whatsoever to see that they are true.

ACTIVITY -9

1. *Differentiate Empiricism, Skepticism and Rationalism*

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2. *In evaporation water is lost or changes its state - What do you think so?*

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3. *Show how is it related to rains?*

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1.6 SCIENTIFIC METHODS

Scientific method is a method of solving problem scientifically. Training in the method is more important than the acquisition of information. Once the student is trained in method they will approach all the problems in the same way, even if they are put in a situation which they are quite ignorant of.

1.6.1 What is Scientific Method?

According to Lundberg "Scientific method consists of systematic observation, classification and interpretation of data". Carl Pearson says "The scientific method is marked by the following features: Careful and accurate classification of facts, observation of their co-relation and sequence, and discovery of scientific laws with the aid of creative imagination and their self-criticism. Scientific method involves reflective thinking, reasoning and results from the achievement of certain abilities, skills and attitudes. It needs a continuous training. For continuous appraisal of scientific method, the teacher should provide such situations and activities as are conducive to its development and training. We shall see some examples:

The problem concerning the whole class in general should be set for study such as "Earthworm composting from the organic waste in the school campus". The whole class will thus be organized as a research team.

Such situation should be created in which a fact well known to the students is posed as a question e.g. Students know that "Evaporation causes cooling". So they can be asked the question "How can you prove the truth of this statement?" Let the students tackle the problem in a scientific way. They themselves will device and demonstrate the experiments.

Individual laboratory experiments which involve some aspects of scientific method may be assigned to the students e.g. growing seeds in the laboratory under different conditions like without any fertilizer, with Bio-fertilizer, with the chemical fertilizer, and with the organic compost. This will provide an opportunity to the students to develop an insight into the scientific method. Scientific method is the combination of inductions, based on their previous knowledge leading to deduction, formulating new knowledge through a systematic process. The systematic process can be conducted under a guided situation by the teacher and gradually students develop capability to work independently through systematization.

An historical event in science or its application may be analyzed. E.g. Newton' law of motion, or "Archimedes Law of the lever".

Have a democratic attitude and join the students in exploring problems, find out the solutions and posing ways of testing data. Give full attention to their problems; Help the students to find way to answer their problem. Never scold the student for any innocent question. Instead of giving direct answer to his question, better suggest such activity and provide situation that the student can find out the solutionsm by themselves to the problems.

1.6.2 Steps Involved in Scientific Method

Any method of solving a problem scientifically following some logical steps may be called as Scientific Method. However, the scientific method consists of the following steps.

i. Sensing the problem

Provide such situations in which the students feel the need of asking some questions. Put such questions which require reflective thinking and reasoning on the part of students and this may become a problem for the students to solve. While doing so the need, capabilities and intelligence of the students should be taken in to consideration, and also the availability of the material on the problem and its utility to the students in promoting reflective thinking. Let us take the example and go step by step.

The teacher demonstrates an experiment to the students to show that Water boils at low temperature under low pressure. He takes the flask and fills it half with the water. Boils the water, and remove the flame. Closes flask and inverts it and pour cold water on the flask. The students observe the process carefully and see that water has begun to boil again when cold water is poured on the bottom of the inverted flask. Students at once sense the problem for themselves of finding out the reason and explanation of what they have seen.

ii. Defining the problem

The student now defines the problem. Teacher should help him in stating the problem. The student may be asked to write down the problem in the light of above criteria and read it in the class for criticism and discussion. The students can give the following statements.

Why is water boiling?

Why did the water boil first?

Why was the flask closed and then inverted?

Why was cold water poured over the bottom of the inverted flask?

Why did the water boil in the flask when cold water is poured over the inverted flask?

Of all these statements, the last one is in fact the problem which should be solved. So this is accepted and the students start analyzing it.

iii. Analysis of the problem

The students now find out the key-words which furnish clue to the further study of the problem. In our selected problem “Water Boils” or “Boiling water” are the key words which gives us clue to find information regarding the boiling of the water under different conditions.

iv. Collecting the Data

The teacher suggests references on the problem; students consult the references and collect evidence bearing upon their problem. The students should be given practice in locating information and to devise means to obtain it. Students shall use devices such as models, pictures, field trips, text books etc.

v. Interpreting the data

It is an important and at the same time a difficult step, for it involves reflective thinking. The students organize the data by similarity and differences, and plan experiments to answer questions and test ideas.

vi. Formulation of hypothesis

After data is interpreted and organized, the students may be asked to write down the inferences based on the given evidence and to propose ways to testing out these inferences. The students can suggest the hypothesis like

Water will also boil.

I When flask is not inverted

II When water is not boiled but only warmed.

III When hot water is poured over the inverted flask containing cold water

IV When hot water is poured over the inverted flask containing boiled water.

V When the cold water is poured over the inverted flask containing cold water.

VI When the cold water is poured over an inverted flask containing boiled water.

Now the students will also propose means or experiments to test these hypotheses.

vii. Selecting and testing the most likely hypothesis

Selecting the most likely hypothesis out of a number of hypotheses requires a special skill and involves analyzing, selecting and interpreting the relevant data. The students can select the most tenable hypothesis by rejecting the others through discussions and experimentations. The selected hypothesis is again tested experimentally to find out its truth. For example, the students have found out that water begins to boil again in an inverted flask when cold water is poured over it. In no other condition this was possible and so all other hypotheses were rejected.

viii. Drawing conclusions and making generalizations

In fact the tested hypothesis is the conclusion to be drawn. However some demonstration can be arranged to arrive at the conclusion. The generalization can be made by arranging a set of experiments which show the same conclusions already reached at. For Example, the effect of varying pressure on boiling point of water can

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be found out by conducting experiments. From these conditions, one can generalize that pressure has a direct effect on the boiling point of water, i.e. the increase in pressure raises the boiling point of water and vice- versa

ix. Application of generalization to new situation

The students should apply the generalization to their daily life. This will bridge the gap between the classroom situation and real life situation. We started the cycle of reflective thinking with a problem, so it is important to close the cycle with application of the generalization to new life situation.

Why is it difficult to cook meat and pulses at high altitude?

Why the rice and pulses take lesser time for cooking in pressure cooker?

Moreover, the application of the principle will help in verifying the principle itself. This is the deductive approach .in which the students can predict and explain different phenomena on the basis of the principle.

In the process of science first define the problem. In the second step formulate a tentative answer to that problem. Then in the third step test the tentative answer by arranging the evidence. In the fourth step develop the conclusion by finding meaningful patterns or relationships. And in the last and the fifth step apply the conclusions by testing it against new evidence. All these five step process is schematically presented in figure 1.7.

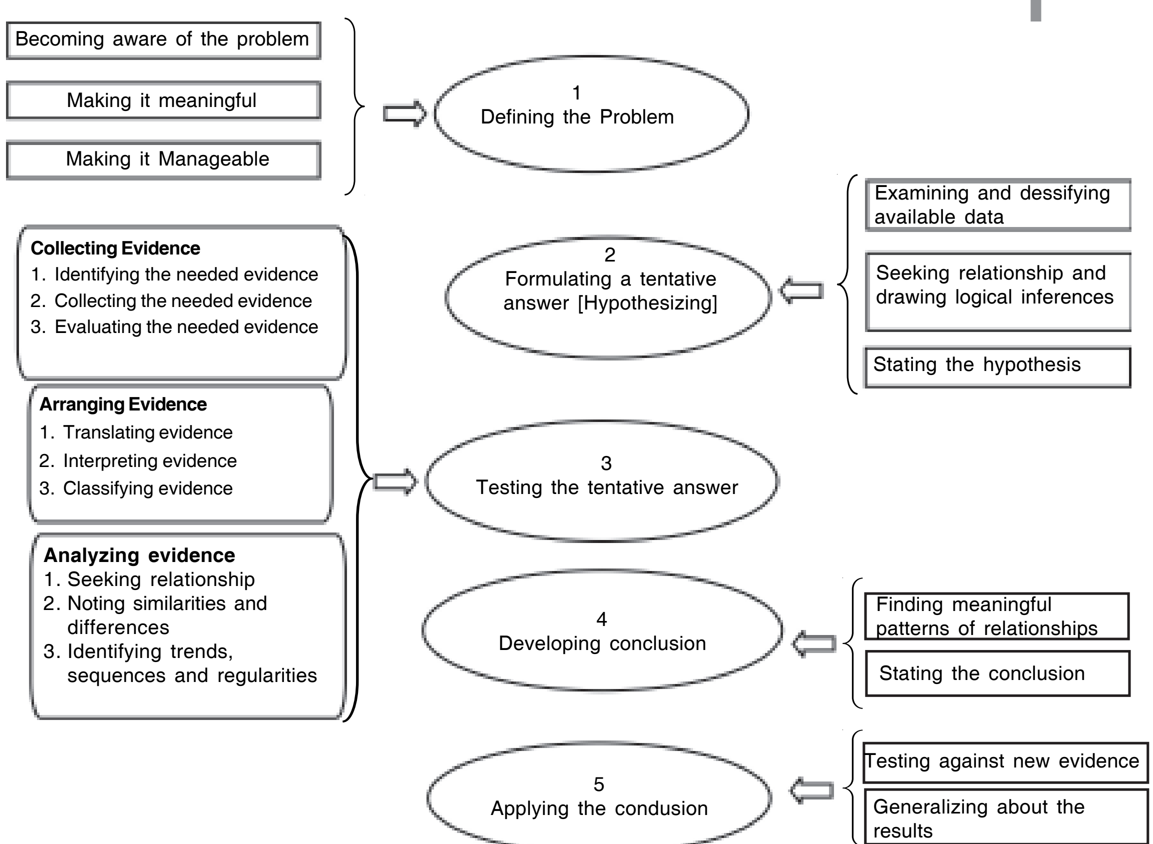

Figure 1.7 The process of scientific method

1.6.3 Scientific Attitude

The scientific attitude is an approach to investigations that benefits from certain traits like:

1. Curiosity or inquisitiveness
2. Objectivity
3. Open-mindedness
4. Perseverance
5. Humility
6. Ability to accept failure
7. Skepticism

Bhaskara Rao (1989) stated that the most useful scientific attitudes are open mindedness, critical mindedness, respect for evidence, suspended judgment, intellectual honesty, willingness to change opinion, search for truth, curiosity, rational thinking, etc. The sole responsibility of developing scientific attitude among the students lies on the teacher. He must present himself as an example to the students for his intellectual honesty, respect for other's point of view, unbiased and impartial behavior in his dealings.

Scientific attitude is really a composite of a number of habits, or of feelings and tendencies to react consistently in certain ways to a novel or problematic situation. These habits, feelings and or tendencies include accuracy, feeling of honesty, open-mindedness, suspended judgment, criticalness ease of acceptance other's view point, and a habit of looking for true cause and effect relationships. It is more of a affective concept; scientific attitudes are normally associated with the cognitive and affective processes of scientists. These habits are important in the everyday feeling and thinking, not only of the scientist, but of everyone. Superstition creates a mental block for scientific attitude to nurture.

Opportunities for practicing work should be provided in schools. This helps in performing and strengthening right attitudes. The students should perform the experiments themselves and find out truth of what they learnt in their theory. They should be taught to suspend judgments until sufficient evidence is secured. They should be instructed to observe critically and accurately and to report only what they see and feel right. Their habit of copying things and taking the things for granted should be discouraged. It is quite obvious that most of the attitudes can be developed through practical work. And at the same time the students get the chance of strengthening the attitudes they have already acquired.

It is not easy to assess the scientific attitude. We are not aware of any satisfactory test calculated to measure Scientific attitude of pupil and very accurately.

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ACTIVITY -10

I asked the pupils to demonstrate the Boiling point of water. After half an hour pupils came to my room and said " sir! We got it. It is 100 degree Celsius."

"Oh fine! Are you sure it is 100" I said.

"Of course, it has to be 100 only. We have been taught like that" Pupils said

"Come on! Let us see" I said. "Look at the thermometer! It shows 98.7, isn't it?"

"Sir, It hardly makes any difference, we must record it as 100 only" pupils said

Analyze the above conversation from point of view of scientific attitude in pupils

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1.7 LET US SUM UP

Indian made a pioneering headway in the field of science. It dates back to 5000 BC. The renaissance started in 1452 AD which was the dawn of science in western world. The early universities like Takhashila and Nalanda could be taken as the first step in the world's institutionalization of teaching. Science is a reliable process by which we learn about all the stuff in this universe. The aim of science is to uncover the real working of natural world which requires straight forwardness, honesty, integrity and objectivity. Science is a community enterprise. Scientific knowledge can be acquired through deducing the guess based on the observations in the form of hypothesis and then formulating it into theory or a natural law. While doing so facts and evidences form the basis of the logical argument. When a specific theory is thrown in to crisis because of significant anomalies, scientific revolution takes place through paradigm shift. Scientific thinking can be Empirical i.e. arising from experience, or it can be Skeptic i.e. based on questioning, doubt, and suspend judgment until sufficient information is available. Or it can be Rational, where reasoning is a unique path to knowledge. Any method of solving problem scientifically following some logical steps may be called as a scientific method. It involves reflective thinking, reasoning, classification of facts, and observation of their correlation, sequencing and then discovery of scientific laws by the aid of creative imaginations.

1.8 ABBREVIATIONS/GLOSSARY

- Abiogenesis: Theory which believes in Life arising spontaneously.
- Biogenesis: Theory which believes in "Life comes from life only", it does not arise in areas that have not been contaminated by existing life.
- Pangenesis: A theory of heredity proposed by Charles Darwin, in which gemmules containing heredity information from every part of the body coalesce in the gonads and are incorporated into the reproductive cell.
- Falsification: It is a logical possibility that an assertion can be contradicted by an observation or the out come of physical experiment. It is the inherent testability of any scientific hypothesis.
- Anomalous: Inconsistent with or deviating from what is usual, normal or expected.
- Cognition: It is a scientific term for mental process including attention, remembering, producing, understanding language, solving problems and making decision.
- Dogmatic: Being certain that your beliefs are right and others should accept them without paying attention to evidence or other opinions.
- Renaissance: Situation when there is new interest in a particular subject, form of art etc. after a period when it was not very popular.
- Creationism: The belief that the universe was made by God exactly as described in Bible.
- Evolution: The gradual development of plants, animals etc. over many years as they adapt to changes in their environment.
- Integrity: The quality of being honest and having strong moral principles.
- Objectivity: Undistorted by emotion or personal bias.
- Recant : renounce, disavow, retract, deny, revoked

1.9 SUGGESTED READINGS AND REFERENCES

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1.10 UNIT-END EXERCISES

1. What is the meaning of Scientific method? Illustrate different steps of the method with the help of an example.

2. What is the meaning of Scientific thinking? Name the different ways of thinking patter? Discuss with example rationalism as a pattern of thinking.

3. Differentiate inductive and deductive inferences with example.

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UNIT 2 SCIENTIFIC INQUIRY

Structure

2.0 INTRODUCTION

As a result of learning first unit of this course, you know that the **science is a human enterprise**. Human beings observe the situations, objects, events, phenomena around

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them. They try to make sense of these. They try to find out patterns of interrelations between various objects, situations and phenomena. They search for the patterns among these interrelationships. Using knowledge of these patterns communities adjust their behaviour, develop customs and culture for leading a comfortable life. By knowing the environment human learned to exploit it for making their living. They developed **technologies as they solved problems by doing everything possible within given constraints**. They also developed **science as they made an effort to reach the best understanding or create an explanation of certain event or phenomenon consistent with the evidence**.

While reading this unit, focus yourself on the processes (skills) that are involved in doing science. Try to understand the processes of inquiring and related skills that work toward doing science. Reflect constantly on your school learning and about your own teaching practices for making reading meaningful.

Time

You will need to spend about 12 hour to complete the reading and doing activities of this unit. But you need to reflect constantly to expand understanding of this material.

ACTIVITY -1

Now ask some questions to yourself for reflecting on your "science learning". This is just a suggestive list and as a responsible member of facilitators' community, you can add your own questions, relevant to your context to it. Write the answers and share your thoughts with your colleagues.

- *Why was I not familiar with various aspects of science after learning science for ten years of schooling?*
- *What did I learn from science?*
- *What message did the text books convey about science as a subject?*
- *Did my science teachers help me to realize that science is way of life and not the information that is to be stored in the books?*
- *What type of class work and home work did I do as science (activities)?*
- *Was I able to differentiate between learning of the science and that of the other subjects?*
- *Did my learning of science help me to make responsible citizens of this democratic country?*
- *Is there any difference between my life and life of the other people who did not learn science through formal schooling?*

  (Are you bothering yourself unnecessarily by asking these questions?)

Did you realize the importance of asking these questions? Share your views with your colleagues and write a short note.

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A note on science text books:

Ask few questions to yourself about your science text books. (Do you think that by asking these questions you are inquiring about your own practices of science learning or teaching?) What do I do when I teach science? Text books are full of facts. Facts are listed along with the description of stereotype experiments and figures (**Recall and recognize).** Cause and effect relationships between various facts and objects are listed along with the description of stereotype experiments and figures (**Understand, analyze and create)** Definitions are given along with examples and illustrations. Classifications are given (**Understand, analyze and synthesize**). What is good or bad is also clarified **(Evaluate**). In short all text books are full of information with many gaps. There is no scope for cognitive activities of level other than recalling and recognizing facts. Learners are required memorize all these facts for writing answers in the examination. Is there any scope for understanding science? Teachers show (or demonstrate) science experiments in the class. Students are told to observe the things that are already listed in the text book. Some teachers did give learners an opportunity to do experiments. But they are just the rituals to be conducted to see expected results.

Very few teachers did care for inviting learners to engage in science, to learn science, to learn about science, and do science by doing scientific processes.

Any time during leaning or while writing examinations there are hardly any opportunities to use cognitive or affective abilities for learners. They are expected to read the information and reproduce the same in examination.

(If you find this text difficult to understand please read it when you are studying units related to objective specifications, teaching approaches, and planning learning.)

2.1 LEARNING OBJECTIVIES

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

- describe the concept "scientific inquiry" and various processes that are required for conducting scientific investigations,
- illustrate the importance of different processes involved in "scientific inquiry" and there importance in persons' life.

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- develop rationale for assisting learners to acquire skills required for undertaking scientific investigations,
- design activities (tasks or experiences) that invite learners to engage in doing scientific inquiry, learning about science and learning science,
- formulate the criteria for designing, developing, and evaluating hands-on experiences, learning environments, and performance of the learners.

2.2 CONCEPT OF SCIENTIFIC INQUIRY

Now, with this background try to make a meaning of the term "scientific inquiry" ("Enquiry" is a British term.). Many thinkers describe "scientific inquiry" as a process of constructing science (knowledge). They think that "science knowledge" is developed by using specific processes. Some people call it as a content of science discipline. For them science could not have come into existence without "scientific inquiry". Some people call it as the meta-content of science because it is a group of thinking and doing processes that lead human beings to construct content of science. To some people it is a state of mind that motivates one to inquire scientifically. Many definitions of scientific inquiry are available in different books and sources. But you work together with your learning community and develop your operational definition that you need for enhancing quality of learning of your pupils.

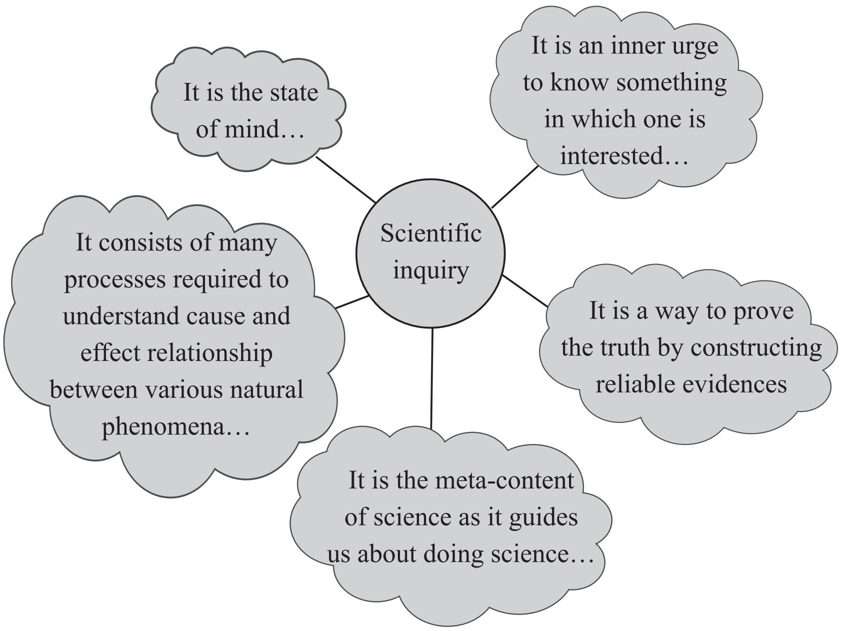

Fig. 2.1 A map showing different perspectives of the term "scientific inquiry"

ACTIVITY -2

You know an example of women belonging to primitive communities. They observed life cycle of the grain or grass plants and their relationship with the seasons. They used this knowledge (augmented time sense) for developing agriculture which is now one of the important branch of science. But how, when and where did this happen? How did "the observation" get transformed into "the knowledge" about life cycle of the plants and its relationship with various climatic factors? How did "the knowledge" get transformed into "the technique of agriculture" and later on into "science of agriculture"? How did mankind learned to control "grain plants" as resource by knowing about plant life cycle? How they know the science of the interdependence of variables involved in different phenomena?

Natural phenomena keep on occurring around human beings. Human brains (mind or intellect) keep on making meaning (sense) out of it. Human brains are wired to be curious, they enjoy being in the curious state (of mind), get excited or like to be in an uncomfortable state, they enjoy the thrill of this discomfort, they search for getting information that is not available to their senses directly, search for answer or solution, they interact with the environment and when they see, experience or find the solution, they become de-stressed and enjoy that state of satisfaction.

And do you wonder about these primitive women of the wandering or cave living communities and the techniques they have developed by interrelating many events that happen around them?

Get yourself into the role of these women who invented technique of agriculture by discovering pattern of lifecycle of grasses. Note down the thought processes that happened in their mind. In short you are expected to imagine a "thought and action journey" of those women who invented technique of agriculture. You can draw a flow chart of this thought process and give a brief note. If you think that you can reconstruct the knowledge construction process related to any other human endeavor, you are free to do so.

Did you able to get the feel of the person inquiring about her or his experiences through this activity? Write in short account of these feelings also.

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Questions for critical reflection

Don't you think that the ability to inquire, discover and invent, by using intellectual and physical tools helped human beings, to know more about their environment and use it as a source and resource? For example, to begin with, people started using caves to protect themselves. When they discovered properties of mud, stones and wood they invented technologies for erecting structures that were better and comfortable than caves to live in. This involved creation (designing and inventing) of needed techniques. The people living in tundra region used properties of snow blocks to build comfortable igloos in their environment. They developed many techniques for making their life easy and comfortable. How did they do this without formal schooling in science (subject)? Did not they construct or rather create technologies to satisfy their needs? They did not know each and every cause and effect relationship involved in the events, they did not prove it with the help mathematical models, they did not able to speak or write (communicate) explanation of their individual understanding clearly, but they all put their understanding into practice. Different communities of the world build up their own theories (technologies, science or sometimes pseudo-science) using their own methods, using material available in their environment. In day to day life every person tries to develop one's own theories about the natural and social environment for managing her or his life.

This only shows that all people are endowed with capacity of doing science. And we as facilitators are here to assist learners to transform this capacity into capability to invent techniques and science. How do you assist learners to do technology and science, using their capacity to do science and in doing so help them to build up their own capability of doing science?

Write in brief critical features of your teaching practice.

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2.1.1 Forms of Inquiry

You can now say that there are two categories of inquirers in our society. One is the category of persons engaged in **scientific inquiries**. They are called as **research scientists**. Their efforts are directed towards understanding natural world. They design and develop tests, evidence, tentative theories, apply them in different situations and remain open for testing these theories with new evidences. For example, evolving a nutritious variety of rice, that can be used for making quality food.

Another category of persons like **student** and **science literates** is engaged in **science related inquiries**. Civil servants, decision makers working in different fields, students

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learning in different grades, farmers are engaged in science related inquiries. They make **reasoned decisions by collecting necessary evidence**. There are three different ways of engaging into this kind of inquiry. Some people use printed and electronic media and many resources to get information. Using this information, they take decisions for personal and social purpose. For example, persons in-charge of developing science parks or science museums read about science and try to understand it. This type inquiry can be called as **archival inquiry**, as data is mainly collected from archaic resources. Another form of science related inquiry is doing experiment based enquiry to verify the claims made **experiment based inquiry**. Students of lower grades or teachers fall in this category. For example students engaged in designing the equipment for making clouds. A farmer uses a piece of land and experiments with the information before practicing it.

Yet another form of this inquiry is doing laboratory work for conducting investigation based inquiry for varied reasons **investigation based inquiry**. Students of higher grades, persons working as decision makers, other persons do this kind of inquiries for gaining understanding of natural world.

Which categories do you belong?

ACTIVITY- 3

Try to recall your teaching learning experiences and developed your own knowledge.

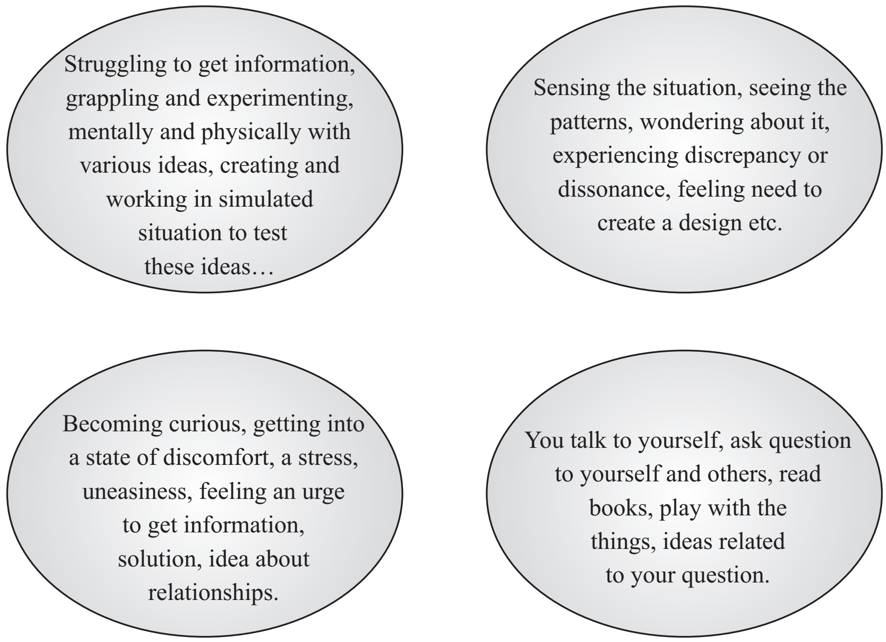

Fig. 2.2 Frames showing various processes involved in scientific inquiry

Read the actions given in circular frames. You are free to rearrange them, drop some of them or add some, draw arrows to indicate beginning and end sequence of actions that you usually do when you undertake some worthy inquiry. When you are doing this, please try to recall incidences in your life that resemble the processes indicated in these frames. Describe these incidences in brief and along with the description of your emotional experience.

ACTIVITY -4

Now you are cognitively ready for expanding your understanding the concept of "scientific inquiry". Study the map of the processes that are involved in any scientific inquiry or investigation. Please remember that this is not the final and rigid description of the concept "scientific inquiry".

While reading this information, keep on connecting it to the understanding attained during earlier discussion and earlier units for making it meaningful.

Now using your understanding of a process of scientific inquiry try to organize above listed actions in the clusters of "information generating process", "information organizing process", "idea building process", and "idea applying process" etc. Please remember that you can add other actions that you think also are part of the "scientific inquiry".

2.3 PROCESS OF "SCIENTIFIC INQUIRY"

Now you are ready to get into details of each process that makes any inquiry a scientific process. Scientific inquiry is a holistic process. To be scientific, any process needs to follow certain rules specific to that discipline. **All processes in science are done with specific purpose, evidences are collected with reliable and valid methods, and they are examined critically by controlling different variables.**

These processes are not natural to human beings and therefore one need to learn them systematically and with focused attention. As learners go through many cycles of learning (experiencing) scientific inquiry, they acquire higher levels of the expertise by doing concerned processes. Development of all these skills involves use of all language skills such as active listening, asking questions and queries, narrating and describing observations, write explanations, search for appropriate words and phrases, coin new words in case if they are required.resources

Observing (patterns), wondering abou objects, events, phenomena, experiencing & sensing discrepancies & dissonance, becoming curious & uncomfortable

Reflecting on various decisions & processes, aiming for better & contextually appropriate solutions, doing thought experiments, assessing personal development …

Deciding purpose, asking answerable questions, refining questions, hypothesising, predicting,

Sharing & presenting ideas, talking to others, receiving feedback, listening actively, arguing

Planning, visualizing & designing for collecting evidence for testing evidence, considering variables, defining ideas, measuring

Making sense of the data, analysing & transforming the data, inferring, reporting findings evaluating the processes and products

Assembling apparatus, conducting experiments, designing workable models, gathering & documenting data, collecting information from various resources

Fig. 2.3 Boxes showing different processes that are involved in scientific inquiry

ACTIVITY -5

Name these boxes appropriately. You can add (or strike off) more processes to each box, reorganize them and draw arrows to indicate their interrelationship.

2.3.1 Engaging Learners in Scientific Processes

Inviting younger children to engage into scientific exploration is the major task of the facilitator. Before getting into the details of components of inquiry skills, please think over following passage.

What is your belief (or concept of) about knowledge? Is it a compilation of facts, conclusions, opinions, guesses, and dogmas? For many thinkers **knowledge** is a mode of **intelligent practice**. Through this intellectual practice knowledge is created, meaning is constructed by gaining experiences, it is shared and negotiated among practicing communities and practiced in day to day life. By practicing these processes a person develops and evolves his or her own method of knowing and personal knowledge.

As facilitators you are responsible for promoting culture of scientific inquiry. Now read more about processes involved in and try to construct your understanding about it. The order of presenting information is as follows:

1. Description of the some critical attributes of the particular processes,
2. Type of assistance needed by the learner to acquire these skills required to conduct these processes,
3. Some of the objective specifications that we can keep in mind for organizing learning experiences, and finally
4. Some examples of the tasks that might help facilitators, in inviting learners to engage in a particular processes. These task demand learners to develop a product that can be used for evaluating performance of the learners.

Please remember that learners will be using their abilities in order to complete tasks given or the tasks in which they are interested. In that process they will develop capabilities related with different skills with higher level expertise. Following boxes show description of various qualities of processes of scientific inquiry.

Unit three discusses various models and methods of learning that assist you to engage learners in various scientific processes and different thinking processes such as inductive-deductive thinking, critical thinking etc. that are required for conducting scientific inquiry.

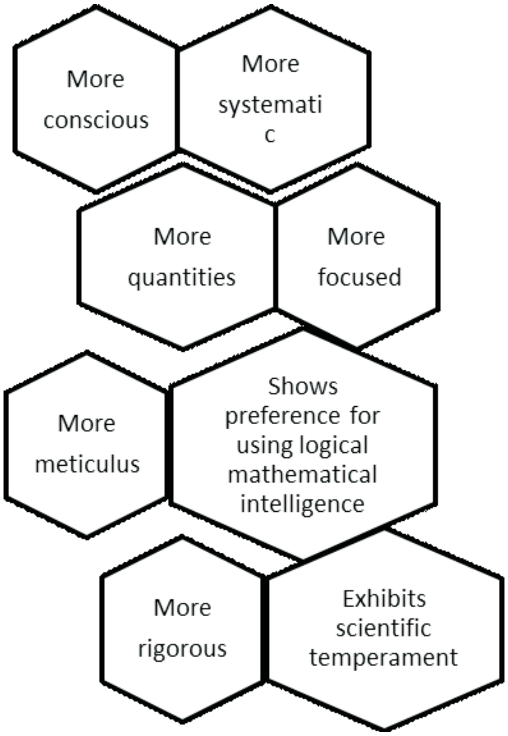

Fig. 2.4 Developing capabilities

2.3.2 Raising Questions for Inquiry

Younger children keep on asking many questions when they are allowed to do so. These questions are resulted out of sheer curiosity about certain things, wonderment experienced due to certain situations or events, experiencing a discrepancies or a dissonance etc. All these questions are not investigable. For this reason we need to assist children to ask questions that serve as starting point for inquiry. The questions may seek for information, a verification of information, a cause and effect relation, an explanation or an idea.

ACTIVITY -6

Process of inquiry depends on the kind of question an inquirer asks. Look at the following list of questions. Analyse each question for specifying degree of inquiry it demands.

Which of the balls bounces highest?

Is the ball better than other one? Is the ball is better for playing cricket?

Why most of the plants have green foliage?

How plants having leaves with different colour make their food?

Why do I experience headache whenever I try to enjoy sweets?

Why most of the animals have red blood cells to help oxygen exchange?

Why am I not sinking in water while swimming? Is my density become less than that of water?

What did Archimedes experience when he enter into water bath that has relevance with his problem?

How will you analyse these questions to decide whether they are investigable or not? Don't you think that analyzing these questions is itself an act of inquiry? If your answer is yes then raise questions that will help you to complete this activity.

Tips for analyzing "inquiry questions" listed above

Here is a suggestive list of questions.

Is it possible to decide the grade of the quality in question by measuring it?

Is it possible to list dependent and independent variables that affects quality in question?

Is it possible to control variables that affect the quality in question?

Is it possible to collect reliable and valid data by designing and executing an experiment?

Does this question make it possible to verify the cause and effect relation in question?

Our goal of developing capability of raising question involves, assisting children to become aware of the fact that only some questions help us to conduct inquiry empirically (by conducting experiments) or by collecting information from archaic material, historical artifacts and archeological material or other resources. They should feel the need to change why and how type questions into investigable questions and work accordingly. Read more about this in unit on approaches for teaching.

Facilitators need to help children to,

- be aware of the possibility of inquiry related to their own question,
- be able to pose investigable questions to satisfy their curiosity,
- clarify their questions to others for helping them to search for the ways for finding answers,
- raise questions while they are reading information by observing a situation or an object.

This understanding of process of raising questions leading to inquiry helps you to identify some specific objectives as follows.

Learners will be able to,

- ask questions leading to investigation,
- ask questions based on hypotheses,
- identify questions that they can answer by investigation,
- devising questions in the form that helps in conducting investigation etc.

Learners' capability to raise questions can be developed by asking them to design sample questions in a given situation. Remember that we need to design situations that are not based on the information that they already have. The situation should be unfamiliar to them. This situation should motivate them to be curious and raise investigable questions.

Sample task: 1 After visiting a temple in nearby town, students were asked to raise questions that intrigued them. Deepu raised a following question: Why all temples have cylindrical columns?

Is this question is investigable? If yes, explain how. If no, explain why. Suggest a question that helps her to conduct an inquiry.

Sample task: 2 Shibu is interested in knowing which colour absorbs more heat. Please help her to design a set of possible (at least two) investigable questions.

Sample task: 3 Salma rose following questions. Help her to select questions that are leading to inquiry by encircling their numbers.

1. Why all natural celestial bodies are spherical in shape?
2. Are all natural celestial bodies spherical in shape?
3. Are there celestial bodies that have shape other than a sphere?
4. Are all bodies that move around their own axis have spherical shape?

ACTIVITY -7

Design one task for inviting elementary learners to use their capacity to raise questions.

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ACTIVITY -8

Why are we interested in helping learners to ask investigable questions? What about the questions like "how herbivores are able to get their protein by eating grass that is a carbohydrate in the form of cellulose?" What about the question like "what did Archimedes found when he entered in the bath tub that has relevance with the "impurities in the gold crown"? Is it investigable or not? why?

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2.3.3 Hypothesizing to Get Directions

On the basis of your prior understanding and assumptions you try to explain data or observations. This explanation is called hypothesis. Here you are using your knowledge or concepts as "tools" for understanding the situation. But to be scientific a hypothesis must satisfy two conditions. **One condition** is that it should be consistent with the evidence. **Second condition** is that it should be testable by supporting it with relevant data.

For example, you observe that a piece of pith of an old tamarind tree log sinks in the water. On the basis of your observation and previous knowledge you can hypothesize that the density of tamarind wood is more than that of water. If all pieces of tamarind wood sink in water then your hypothesis is consistent with evidence. If a piece of particular part of the log sinks in water but not all, then your hypothesis is not consistent with the evidence. For testing this hypothesis you can collect data by sinking pieces of tamarind log of same size, same weight, form different trees and sampled from different parts of the logs. To be testable, a hypothesis there should be a possibility of collecting evidence. There is some invisible and undetectable force in tamarind wood that forces it to sink in the water is untestable hypothesis. There is no possibility of collection of data to test this hypothesis.

Behaviour of any object depends on many variables at a given instance. For studying water retaining capacity of soil, you need to test it on the basis of size of particles, percentage of humus, its adsorption capacity etc. By conducting investigation to test these avriables, it is possible that all hypotheses might get eliminated. If some hypotheses do not get eliminated there is every possibility that further evidence might disprove it. **Again one must keep in mind that any sound and reliable evidence that disapproves it, it is sufficient to reject it. That is why any scientific knowledge is always accepted as tentative truth and not as eternal truth. This is one of the important characteristic of hypothesis.** These also give you a rationale for assisting children to experience process of "scientific inquiry".

Major steps involved in the development of hypothesis (testable explanation).

One has to learn to develop testable hypothesis as it is not a natural ability. There is every possibility that you might end up in giving illogical explanation. **And if one is reluctant to collect evidence for accepting it as a truth and it is a pseudoscience.**

Step 1: For developing a hypothesis, one needs to identify characteristics of an object, event or phenomenon that is relevant for giving an explanation.

Step 2: Then one needs to connect it with some relevant idea that you experienced previously. Here one should insist on giving cause and effect relationship between two variables.

Younger children due to their limited experiences, come up with many impossible explanations. Facilitators should assist them to understand this.

Facilitators need to assist learners to,

- make an effort to use some idea or concept for explaining the observation or relationship,
- use concepts or ideas acquired in one situation to explain other situation,
- put forward many explanations that are possible with respect to one situation,
- put forward an explanation that is verifiable,
- suggest testable explanation though they feel that it is not correct one.

By now you are in a position to list some of the specific objectives related to process of hypothesizing.

Learners will be able to,

- explain a situation in terms of familiar concept or information,
- develop more than one explanation,
- judge the testability of given explanation, etc.

Here are some sample tasks that are designed for inviting learners to use their abilities to develop hypothesis.

Task 1: Santu and her friends were walking to the school. There were many trees growing along the side of road. They have observed that there were nests of weaver birds only on some variety of trees. They are puzzled. Please suggest two explanations for this that can be tested by collecting relevant data.

Task 2: Muthu's house is surrounded by trees and flower bushes. He observed that flower bushes growing under the trees are taller than those growing in the open. He came up with following hypotheses.

Bushes growing under the tree don't get bitten by heavy rains.

Bushes growing under trees are getting fertilizer that is given to the trees.

The soil under trees contains more compost due to rotting of tree leaves.

Bushes under the trees grow tall as some force present in trees force bushes to grow.

Which of these hypotheses is testable? How?

ACTIVITY -9

How will you encourage learners to put forward their own hypotheses? Suggest one activity.

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2.3.4 Predicting for Getting Direction for Observations

You predict the result on basis of evidence or past experience. There is always a rational for prediction. Before doing any action you predict the outcome to avoid risks. On many occasions children fail to explain basis for prediction but they can be helped to articulate the related evidence or past experience.

Facilitators need to assist learners to,

- make predictions before carrying out any action,
- articulate rationale of that prediction
- justify reliability of prediction with respect to particular situation

Now you can list some of the possible objective specifications related to the development of skill of prediction.

Learners will be able to,

- articulate rationale for prediction in question,
- make explicit past experiences related to prediction,
- justify prediction on the basis of inductive conclusion etc.

Here are some items designed to help you to invite learners to develop their capability to do prediction.

Task 1: Observe the following table and enter correct alternative in the empty cell.

10 years, 100 days, 100 years, 30 years, 300 days

Planet	Distance from the sun in km	Days required to complete one round
Mercury	58×10^7	88 days
Venus	108×10^7	225 days
Earth	150×10^7	1 year
Jupiter	780×10^7	12 years
Uranus	$2{,}870 \times 10^7$	84 years
Imaginary	$1{,}430 \times 10^7$	

Justify rationale for selecting the particular alternative.

Task 2: Jeetu and Wilie are playing with two bar magnets of same length. They decided to tie two bars with opposite poles together and hang them on a wooden stand. In what directions will they get aligned to?

Justify your prediction.

ACTIVITY -10

1. *What role does the skill of prediction plays in making any inquiry "scientific"?*

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2. *Why is it necessary to develop skill of prediction while learning science?*

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3. *Design one activity that invites learners to predict the result?*

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2.3.5 Observing for Collecting Information

Many of the actions that are involved in scientific inquiry come into existence after keen observations of certain things. Due to this a person become curious and sets out for inquiry. For scientific inquiry, one needs to raise questions, put forward hypotheses, do predictions, take measurements and these activities require one to observe situations deliberately and carefully. Decision about observations is taken on the basis of previous knowledge and observations.

Observation as process needed to conduct inquiry, demands one to use all senses, and collect relevant information with respect to hypothesis. For observing details of relevant aspects, sometimes specific instruments are needed. For example, if a question is, how long does it take for a lump of jaggory to get dissolved in cold and hot water? Is it not possible to observe time accurately for comparison without valid instrument? At elementary level learners can be helped to invent crude methods for measuring things. Learners are needed to design a method of observation. Thus there is a need to learn to decide purpose of observation. If one wants to observe earthworm engaged in the process of vermicomposting a particular type of arrangement is needed. For example, can we put the sample in large cold drink bottle? 0r Do we need a transparent bucket to do this?

Processes of observation is completed with the process of documentation. Documenting the observations and organizing gathered information comprehensively is also an important skill. Documentation skill involves noting date, time and duration of observation, placing the sample in proper position to get useful perspective, sketching labeled drawing of the sample, dissected living plant or animal, taking sections of different kinds with different purpose, creating a useful table, make a labeled drawing of arrangement of experimental equipment, develop appropriate tables etc.

In order to develop these capacities facilitators need to assist learners to,

- decide purpose, method and place of observation
- make detailed and focused observations
- make them talk about their observations and share it with others
- be critical while evaluating these observations
- make plans for documenting these observations

A note about observations

There is a tendency in all persons to see what one expects to see. One must remain alert about the influence of preconceived ideas on our observations. Many times preconceived ideas prove to be a hurdle in our observation. They either blind you from seeing new aspect that remain unnoticed or you fail to remain open for observing what comes in your ways without restricting yourselves to certain perspective. Learners should be helped to remain alert with respect to this problem.

With this information about observation process, now it is easier for you to decide the objective specifications for the same.

Learners will be able to,

- use all possible senses for gathering information,
- identify differences and similarities between different events and objects,
- identify critical features of events or objects,
- decides the procedure of observations, documents the observations, etc.

After writing objective-specifications you are in position to devise tasks.

Task 1: Look carefully at the sketches of a spider and an ant. On the basis of these pictures, list three similarities and three differences between these animals.

A spider

An ant

Fig. 2.5 A Spider and an Ant

Task 2: Sonu put some seeds in the water for eight hours. She was expecting them to sprout. After separating them from water she found that only some seeds have absorbed water and other remained hard. Now she wants to collect evidence for her hypotheses that are listed below. What details should she observe and how with respect to each hypothesis? Explain in detail.

Hypothesis	*What needs to be observed?*	*How should it be observed?*
There is no hole for water to enter inside the seed. The seed coat is not made up of absorbent material. The seed is dead and so it did not absorb water. The temperature of water was not soothing to the seed for generation		

ACTIVITY 10

Design one item to test learners' capability to make observations.

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2.3.6 Searching for Patterns and Relationships

Evidence in the form of mass of isolated pieces of information or facts is of no use in the process of inquiry. For this purpose the inquirer should analyse and reorganize it to see patterns and relationships. For example, there is a relation between increase in the medical facilities and the population growth of an area or increase in the medical facilities and growth in the percentage of senior citizens in a given population etc.

Sometimes data do show a particular trend but there are many exceptions. In science it is important to take a note of these exceptions before jumping to the conclusion.

It is important to have at least three sets of observations if we are looking for pattern between two variables. Best (scientifically appropriate) way is to claim the existence of relationship on the basis of two sets of observations. Then look for the third set of observations to refute the claim about relationship. For doing this one has to check all suggested relationships by making prediction on the basis of relationship claimed to exist. Then see whether that prediction fits in the claim or not.

Capability to do this can be acquired by going through many cycles of learning.

Facilitators need to assist learners to,

- look for the pattern in day to day life,
- express their ideas about different patterns,
- search for the evidence when they make any claim with respect to any pattern or relationship,
- verify the relationships on the basis of supplied information.

You can now write objective specifications on with respect to skill of finding patterns and relationships

Learners will be able to,

- analyse different pieces of information (collected from observations or secondary source) and synthesize them to infer meaning,
- search for the recurring behaviour among observation and describe it,
- identify relationship between two or more variables, justify why an inference should not go beyond available data,
- validate the relationship on the basis of supplied information etc.

Now it is possible to design some tasks that demand learners to exhibit the intended behaviour.

Task 1: Recently, Mini visited the institute of silviculture (science of forest). There were framed transvers sections of tree logs and the age of tree was written on each frame.

Task 2: Fuli and her friends were on the nature trail. There they found many banyan trees among all other trees. These trees were full of nests of storks (a variety of bird-bagula).

Which of the following statements, you can be most sure is true just on the basis of given information. (Underline the statement) Justify your selection.

The banyan tree is most suitable for building nests of storks.

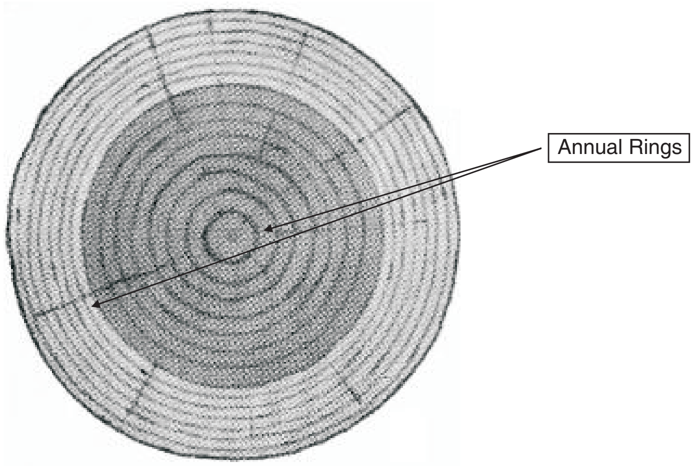

Fig. 2.6 Transverse Section of a Log of Wood showing Annual Rings

The banyan tree offers good protection from wind, heat and rain.

There are many nests of storks on the tree.

Banyan tree attracts many insects during its fruition period and storks feed their chicks on larvae of insects.

Banyan tree is strong enough to hold many nests of storks.

ACTIVITY -11

1. *Design one activity for assisting learners to acquire the process of searching patterns.*

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2.3.7 Devising and Planning Inquiry

These two processes need considerable experience in executing an inquiry. Younger children are interested in seeing the things happen and hardly have patience to wait for planning. This happens because when you raise question and ready with hypotheses with you, you are eager to get evidence.

For devising and planning inquiry one needs to think about variables that play important role in the process of inquiry. In all there are three categories of variables.

Independent variable: To investigate difference between two things or conditions you change these variables. The difference between things can be compared on the basis of some property. For example, if we want to investigate heat absorption capacity of colour with respect to certain type of fabric then the colour is the independent variable. It will not be changed during the experiment.

Control variable: The investigate heat absorption capacity of the colour you should not change some variable during the study. For example, you will not change the type of cloth, duration for which the heat is supplied; temperature of the source will also be kept constant throughout the investigation.

Dependent variable: This variable gets affected as you change the independent variable. That is why it is called as dependent variable. In this example heat absorption capacity is a dependent variable as it depends on type of cloth, temperature of the source, duration for which the heat is provided etc.

All these variables need to be considered to devise a “fair” or unbiased test for collecting evidence. When children are egger to conduct investigation they need to think about control variables in order to compare independent variables. Learners also need to think about what to measure, or what is to be compared in advance. Similarly they also need to decide about procedure for measuring dependent variable with appropriate degree of accuracy.

Facilitators can assist learners to play a role of investigator and acquire different skill by practicing these skills as beginners as follows,

- to sense problems that can be investigated by them
- to plan investigation systematically and with patience
- to reflect on their thinking and their practices
- to review action plan and develop improved plan

On the basis of above discussion you can list some objective specifications as follows.

Learners will be able to,

- decide about different variable to be taken in to account to conduct investigation,
- decide about devising equipment and material needed for inquiry,
- select about procedure for controlling variables,
- develop procedure to measure dependent variable accurately etc.

Now you can devise tasks for inviting learners to develop capability of devising and planning.

Task 1: Zuri wants to study the difference between cotton, silk, wool and synthetic fabric so that she can select fabric for stitching a dress for winter season.

What is the independent variable in this investigation?

What are the control variables in this investigation?

What is the dependent variable in this investigation?

Identify the quantities you need to measure in this investigation?

Task 2: Janu's family lives in village where medicinal plants grow in plenty during monsoon. There is one variety of plant that has flowers with greenish yellow petals. As days pass, petal colour changes to reddish yellow. Then shade change to red, then to dark red before flower whether outs. Janu wants to test hypothesis "shade of petal changes because PH value of material of petal cell changes".

Make a list of material and procedure needed to test this hypothesis.

ACTIVITY -12

Design one activity to assist learners to experience devising and planning inquiry.

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2.3.8 Designing and Making Equipment

These are technological processes that are required to conduct inquiry scientifically. Technological skills are developed while using knowledge and resources that are available to a person or community. For example, man used his knowledge of fire and developed techniques of creating fire and controlling it. Similarly by observing rolling objects he developed his knowledge about it and then designed rolling objects and perfected the technique of designing wheels. Thus technology involves designing a procedure, a recipe, a tool, a device, a machine, a method etc. We can say that technology is a human activity of using knowledge and resources to control the things or resources, make thing work automatically or with minimum efforts, constantly improve the way things work.

Though the knowledge used for designing any techniques is scientific and mathematical in limited sense, their relationship is obvious. For example, when man invented technique of making fire he had limited scientific knowledge about fire. Scientific knowledge is used for designing solutions to practical problems that we face in daily life. Thus for building a structure, knowledge based systems approach is used.

Younger children while engaged in playing, design many things and techniques using available material. For example, they use waste paper, cloth, boxes, sticks, dry leaves, seeds, glue, and plastic sheets for building play houses. They use different kinds of circular things to play with. Progressively children plan their designs with quality criteria, choose right kind of material, make precise use of tools, they devise test to check sturdiness of the design if given opportunities. In a process they learn to make measurements for comparing artifacts, their cost and utility.

Facilitators can assist learners to develop skills required for designing and making by giving them opportunities,

- to improve the quality of environment by modifying thing around them or creating new things that have some practical use,
- plan artifact or solution; describe it to others and then discus how far it is practical,
- to explore properties of the material that are present in their environment and experiment with it systematically,
- select a problem that might look simple but is challenging, etc.

With respect to the process of designing and making you can have following objectives and specifications.

Learner will be able to,

- choose the appropriate material for developing things that are expected to serve the purpose decided in advance,
- design realistic solution that can be put to use,
- design and make artifact that satisfy previously decided quality criteria etc.

This process involves practical work and necessary period for working out the solution needed is longer. Some situations that demand designing are suggested.

Task 1: Your family is going out for a week and there is a small plant in your courtyard. You cannot keep it outside because it may get damaged. Develop a device that will water the plant-pot regularly and evenly for six days.

Task 2: How will you find the thickness of a page of your notebook using compass box ruler? What measures will you take for accurate measurement?

ACTIVITY -13

Design a strategy for inviting learners to use skills related to designing and making something that has some practical use.

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2.3.9 Manipulating Material and Equipment

Activities of science involve putting ideas in action and test their workability. It is not expected that learner with their limited experience should work as scientists. But learners should know that ideas should be consistent with the evidence available to them at any time. At least they should realize that ideas cannot be called science unless they are supported by string of evidence. To large extent development of ideas depends on practical activity that aims at exploration of material. When one experiences or encounters objects or events in reality then they can be used for thought experiments and for mental manipulation of objects. This enables persons to handle equipment effectively. Practical activity must begin with planning. Planning involves hypothesizing, predicting, designing and observing, collecting information by controlling variables, interpreting findings, communicating the results etc.

There should be a plenty of material around for learners to explore. Parents help can be sought to assist children to explore the material and instrument around them. They should be also made to take precaution regarding various things around them. For example, many children are curious about electricity and electrical equipment, they like to handle tools like knife, scissors, cutters, saw, hammer etc. with needed care. While exploring living world, learner should handle living things with due respect and care, avoid hurting them as far as possible, should not leave them to die in pain.

The skill of manipulation of material and equipment can be facilitated by,

- designing learner friendly and open learning environment,
- encouraging learners to go beyond just completing activity, construct the things and improvise the construction constantly.
- organizing demonstrations for learners to observe and question use of tools and equipment effectively, economically, safely, preservation of tools and equipment for future use etc.
- helping learners to remain alert about their inquiry by reflecting during action.

You can thus list some of the objective specifications as follows.

Learners will,

- handle and manipulate the material and tools with care and efficiency,
- use tools effectively and safely, assemble equipment appropriately for carrying out observations,
- work with precision with respect to the task at hand.

Process of manipulation and exploration material involves practical work and hardly leaves any scope for any exclusive task. It will be integrated with other tasks. For example, learners can be asked to design a working model to explain eclipse.

ACTIVITY -14

Design learning activity that demands learners to have an idea and then explore it practically.

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2.3.10 Measuring and Calculating

Quantification of various quantities like length, weight, humidity, temperature etc. is unavoidable in any scientific investigation. Learners can use their number sense to label or number the things, sequencing the objects or observation in certain order, compare various qualities of different objects in terms of various quantities. Here leaners need to understand the necessity of having uniform units, limitations of arbitrary units and selection of appropriate tool for measuring particular aspect (variable) of investigation. Similarly selection of appropriate unit of measurement is also important.

It is important to remain alert while conducting experiments and do measurements. How to avoid and minimize personal and tool errors while conducting observations should be a part of the planning. For example, learners need to understand relevance of taking repeated measurements.

Using sense of numbers for measuring and calculating relationships is important with respect to scientific process. Developing mathematical models with respect to investigation in question or selecting available mathematical model are also relevant skills.

Learners can be assisted to develop these skills by asking them to,

- use valid standard or crude measure for making comparison,
- taking sufficient number of measurements,
- selecting correct instruments and use them correctly for taking measurements,
- using correct mathematical processes and concepts etc.

On the basis of this some of the objective specifications can be listed as follows.

Learners will be able to,

- measure the relevant quantity in a given situation to compare a needed quality,
- select appropriate unit and instrument,
- do calculation by selecting appropriate mathematical process etc.

Notes

Now it is possible to design tasks for inviting learners to use measurement and calculation processes.

Task 1: Shaba wants to compare stomata of jackfruit and teak leaves.

What information should she gather?

How should she select the samples?

What should she observe?

How should she observe to get necessary information?

How should she present the comparison?

What instrument is suitable to compare the areas of the leaves?

Which mathematical process will give her a valid result?

Task 2: Madho's grandmother is illiterate but knows everything about environment and he enjoys learning with her. One day she told him, "From now onwards the Sun will start moving in south direction." She also showed him how the directions of early morning rays are changing every day. Now, Madho wants to prove this mathematically. Help Madho to design a plan for observing the shift in the direction of Sun rays and calculate shift per day. (Help him to decide and do what to observe, why to observe, when to observe, what to measure, how to measure, how to calculate relationship etc.)

Question for critical reflection

Do you think that if learners are given opportunity to practice mathematics while doing science they will develop better sense of numbers? Support your answer with logical justification.

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2.3.11 Articulating and Communicating

At each stage of scientific inquiry, inquirer needs to articulate and note down his or thinking clearly to herself or himself. This is necessary to examine the clarity of thinking processes and level of understanding. Communication also involves organizing data, presenting it using mathematical models, drawing graphs, developing procedure or process graphics, using different type concept tools to represent ideas and relationships, answering queries with honesty, arguing rationally, etc.

Communicating one's understanding about natural word, developing reports for adding to the knowledge base for the benefit of community is important also a necessary task.

For using appropriate terms, words, and phrases needs learners to have good command on vocabulary. For example, when a spoonful sugar is placed in lemon juice it dissolves in it but learner might record it as "sugar melts" in water. At this point it is necessary to help learners to engage in critical discourse. They should be able to compare these two processes with evidence.

Facilitators should remember that helping learners to engage in various processes of inquiry is not sufficient to ensure the acquisition of these skills. Scope should be given to learners to discuss their thinking in large or small groups. At same time learners should confer with learners to help them develop report of their personal progress.

Learners need to help learners to use their language and communication skill by creating opportunities,

1. write logs of their thinking process,
2. prepare journals of conducted experiments,
3. develop representations for communicating ideas, concepts, understanding, findings, etc.
4. develop artifact which are developed using understanding of natural objects, phenomena or events in the form of street plays, drams, exhibitions, carton strips etc.

On the basis of this information you can write objectives specific with respect to communication skills.

Learners will be able to,

- represent data, findings, understanding using graphics, tables, charts, concept maps, etc.
- interpret the data scientifically to use it for personal or professional purpose,
- read information from various resources and reconstructs simulations using available material,
- write a story on basis of understanding using different forms, autobiography of calcium in "calcium cycle" or "chemical journey of calcium".

This will help you to design relevant tasks.

Activity 15 (to be completed after reading unit four)

Design hands on learning experiences that focus on scientific inquiry. How will you create a scope for learners to experience active listening and collaborative working?

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2.3.12 Self-reflection for Self-actualization

As a result of advancing in scientific inquiry a person must be able to get freedom from egocentric thinking (self-centered view) , intellectual provincialism (not ready to listen to other point of view), and anthropocentric world (limited exposure to cultural differences) view. Through the process of reflection learners can help themselves to manage the stress of learning and completing work systematically. Self-talk along with dialogue with peers and experienced others assist learners to acquire skills related to self-awareness, self-regulation, self-improvement, and learning how to learn.

For this facilitators should create opportunities for discourse among learners with respect to inquiry processes and personal development. Here encouraging learner to open up their apprehension while working with other people, talk about their beliefs, accepting oneself with all shortcomings, trying to overcome mental blocks, struggle with one's weaknesses is necessary.

Writing personal diary of goals of learning and development, preparing and maintaining self-progress book, planning journey toward one's goal, working on basis of pre-decided criteria to evaluate one's progress, developing artifacts individually and collaboratively are some of the useful strategies.

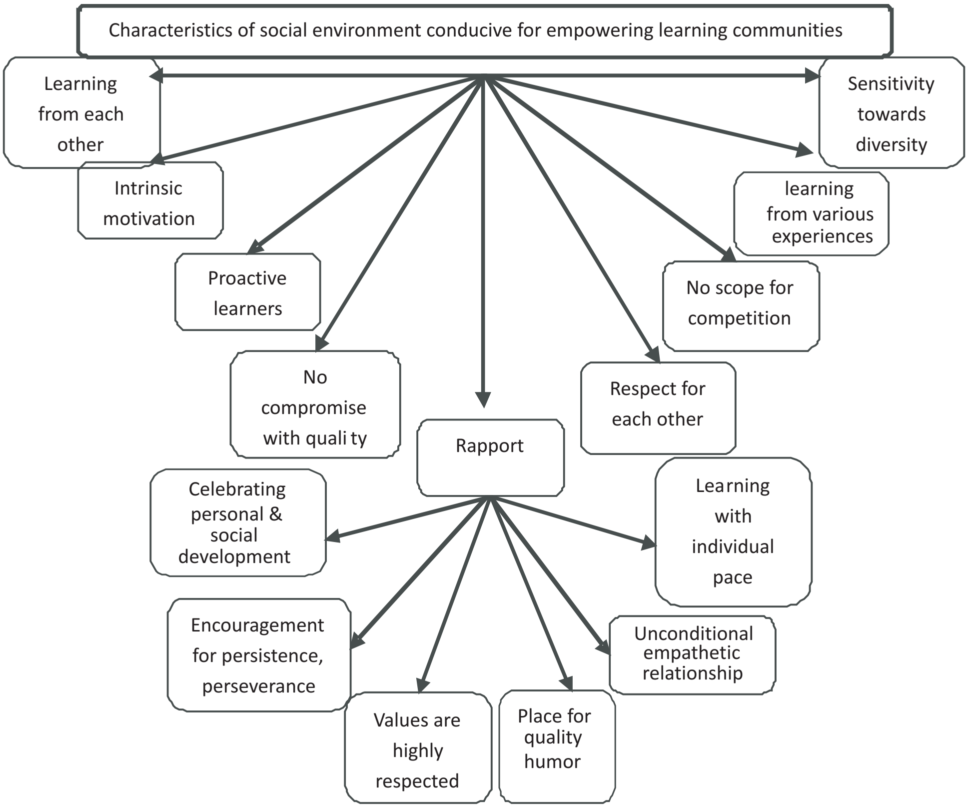

Fig. 2.7 Characteristics of social environment conducive for empowering learning communities

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Goal of inquiry is to expand ones perspectives and relationships with environment and enjoy life fully. This wholistic perspective of development is described in the figure. The circle showing expansion are attached to each other, indicate that self has to manage with many relationships.

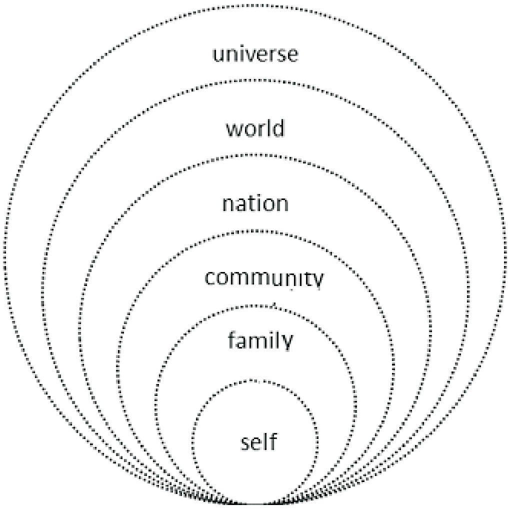

Fig. 2.8 Wholistic Perspective of Development Environment

ACTIVITY -16

What approaches will you adopt to do away with the environment of competition that burdens learners with stress and anxiety?

Develop a list of suggested activities to promote atmosphere of collaboration as well as search of self.

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2.3.13 Inquiry in Personal Life

A person, a botanist was tested for a cancer. He asked himself some question. What this cancer means? What is the cause of this cancer? Is there any cure? How long a patient of this cancer does live? He did not ask questions like, “why me?”, “why did god/ my destiny punished me?”, “Is it a curse by some angry god or goddess?” etc.

He went to the library with his questions and within couple of days he knew all about that particular type of cancer. He also studied statistics about life span of patients and inferred that he probably he will be living for at least one year. He thought that probably during this period scientist and doctors will be ready with an effective remedy to tackle this problem. He decided to take all possible care of himself.

The person thus lived for many more years happily managing his life.

In short by asking investigable questions this scientist decided to do thing that he can control. At this instance he was not in the category of research scientist but he was engaged in doing science related inquiry.

We want our learners to have control over their life, they should not try to bribe destiny through any god or god man. They should not wait for the miracles like doubling of money or ornaments or raining of jewelry.

Question for Critical Reflection

What is the importance of inquiry skills in your personal and social life?

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2.4 LET US SUM UP

In this unit efforts were made to make you familiar with the concept "scientific inquiry". Please remember that this unit is just an overview of scientific inquiry. By now many of you must have developed an interest in knowing more about implementing scientific inquiry. There are many books based on this concept. Many processes needed for undertaking scientific inquiry can be developed by promoting a culture of asking worthy and investigable questions. It is also important to complete inquiry process with determination and honesty. As facilitators we need to create scope for learners to experience different process of inquiry systematically. Learning and performing, performing and evaluating performance, doing actions and reflecting on those actions are not separate processes in this type of active learning. Different processes are learned by doing inquiry and not by reading questions and answers from the prescribed text books.

2.5 SUGESTED READINGS & REFERENCES

http://science.education.nih.gov/supplements/nih6/inquiry/guide/info_process-b.htm

http://www.thirteen.org/edonline/concept2class/inquiry/

http://www.nap.edu/openbook.php?isbn=0309064767

http://tessa.ed.psu.edu/Header_Documents/TESSA_Overview.cfm

http://www.ehow.com/info_8342420_2nd-activities-teach-scientific-inquiry.html

http://bjsep.org/getfile.php?id=88

http://faculty.mwsu.edu/west/maryann.coe/coe/inquire/inquiry.htm

http://encyclopedia2.thefreedictionary.com/thought+experiment

2.6 UNIT-END EXERCISES

1. what are the forms of inquiry? Differentiate between archival and experiment based inquiry with examples.

2. Narrate the order of the scientific process for learners' engagement in preparing bio composting.

3. Discuss the types of variables with suitable examples.

Notes

UNIT 3 DIFFERENT APPROACHES TO TEACHING OF SCIENCE

Structure

Notes

3.0 INTRODUCTION

A set of human behaviours is infinite. Similarly a set of teaching behaviors which is a subset of human behaviours is also infinite one. For every element belonging to the first set, there exists a corresponding element in another set. In short, these two sets are equivalent. Then question arises, what is the distinguishing characteristic between these two sets of behaviour? The distinguishing characteristic is the difference between their intentions. Teaching behaviour is intentional; its basic intention is: Somebody learns something. (P learns X)

The intentions can be simple as knowing the name of an object and as complex as development of the character of students. The complexity of the teaching varies directly according to the complexity of its intentions. This complexity is greatly increased when the teacher interacts with different types of the students in different classroom settings and that too under numerous constraints of time, resources etc. Many experts have tried to define teaching but there is no agreement on the definition of teaching. But generally they agreed upon the following definition as:

"Teaching is an interactive process between the teacher and the students in classroom situation with predetermined objective to be achieved, and its effects can be measured in terms of both immediate and intermediate product variables."

On the basis of studies on research on teaching, there exist three distinct different mathematical equations which can describe teaching. These are as follows:

Table 3.1 Teaching as a Mathematical relationship

Sr.No.	*Author*	*Relationship*	*Teacher's role*	*Students role*
1	?????	X—Y	Authoritarian	Passive
2	Henderson (1969)	X—Y—Z	Moderator	Less passive, more active
3	Jones & Bhalwankar (1986)	In W, X—Y—Z	Facilitator	Totally active

X- Teacher, Y- Subject, Z- Students, W- Learning Environment.

Out of these three equations, the first equation is dominating the classrooms as on today also. In order to use other two equations it is necessary to use different method of teaching by the teachers. After studying this unit you will be able to evolve your own style of teaching by blending all the method appropriately while teaching in the classroom. This is necessary to keep the quality of teaching and schooling very high.

3.1 LEARNING OBJECTIVES

After going through this unit, you will be able to

- describe different approaches of teaching such as expository, discovery, and inquiry.
- differentiate between all the approaches of teaching.
- explain the relationship between all the approaches of teaching.
- use the methods to different units from Science.
- develop lesson plans based on a particular unit with respect to all the three methods of teaching.
- explain different units of Science from the perspective of three methods.

3.2 METHODOLOGY OF TEACHING

Well known American Psychologist of the last century B. F. Skinner (1971) had said, 'You can teach anybody anything provided you know how to teach'. This highlights the importance of pedagogy/ methods of teaching at all levels of education. Therefore, if one analyses any curriculum of teacher education, one finds that more weightage is given to methodology of teaching courses. In some teacher education programmes methods and /or contents of school subjects are taught, whereas in some content-cum-methodology is taught to the prospective teachers. However, Methodology of Teaching has been at the heart of the teacher education programme throughout the world. In order to learning to happen in the classrooms, teaching behaviours should occur in a sequence. These sequences can be classified into different meaningful categories such as strategies, methods, patterns etc. The definitions of method are given below –

The relationship established by an educational institution with a group of participants, for the purpose of systematically diffusing knowledge among them.

Henderson (1963, p.1007) observes – a pattern that is set of common properties that a set of behaviour manifests will be called as a method.

According to Broudy (1963,p.2) methods refer to the formal structure of sequence of acts, commonly denoted by instruction.

These definitions clearly indicate two important aspects of the method:

(a) Systematic organization of the content.

(b) Imparting knowledge and methods of acquiring it.

Table 3.2 Relationship between Different Approaches of Teaching

S.No.	*Parameters*	*Expository transmission Approach*	*Discovery Approach*	*Inquiry Approach/ process skills*
1	Cues	All cues provided by the teacher	Some cues provided by the teacher	No cues provided by the teacher.
2	Structured ness	Highly Structured	Averagely structured	Low structured
3	Teaching-Learning process	Totally teacher centered	Moderately teacher centered	Totally Student centered

From the table it is very clear that all the three approaches are not mutually exclusive but related to each other. All the three approaches differ with respect to cues, structured ness, and the involvement of the teacher and the student in teaching learning process. In **expository approach** all the cues provided by teacher while teaching, the deductive thinking where in abstract content is differentiated by the teacher giving appropriate examples to the students. Teaching Learning process is totally controlled by the teacher. In **Discovery Approach** some cues in the form of a learning material is presented by the teacher to the students and using Inductive thinking, the students are expected to discover the concept or the generalization/rule. Therefore the teaching learning process is partially controlled by the teacher and students also involved to a great extent. In **Inquiry approach** the students are given a problem or a discrepant event. The students will ask the teacher questions to collect the data and they through interaction find out a satisfactory solution to a given problem or explanation to the given discrepant event. In this approach the teaching learning process is totally controlled by the students.

As a teacher, one has to teach facts, concepts and rules/generalizations across all the subject matter and all levels of education. Henderson (1963) has systematically analyzed thousands of audiotapes of classroom teaching of mathematics teachers. He has identified the four general teaching moves, which are required to teach any rule. These are given below:

Statement of rule (SR): (Assertion move)	A statement of rule under study may be made either by the students or the teacher
Clarification of the rule (CR):	Through the use of examples, demonstrations, evidence of proof, discussions of sub rule.
Justification of the rule (JR):	This move identifies the veracity of that which is under study, cross-proofs, opinions of experts etc.
Application of the rule (AR):	In order to insure that the students are able to take learned rules into other settings, there must be some form of practice

Different methods can be generated by making use of one or more moves referred above and changing the sequence of these moves. In short all the three methods are not mutually exclusive but are related to each other. Therefore, it is highly essential for every teacher need be conversant with these moves so that depending on subject matter, availability of resources, time, etc. he/she can select and execute appropriate method(s) while teaching in the classroom

In short, the concept of method can be stated in terms of a Mathematical equation as

Method of Teaching = Content + Processing of Content

How the content can be processed in the classroom by teacher is explained in subsequent sections. Effectiveness of teaching largely depends on the method used by the teacher in the classroom. Effectiveness of teaching is just like a Mathematical ray which has a starting point but no end point at all.

3.3 EXPOSITORY APPROACHES OR TRANSMISSION APPROACH

Expository Approach is also known as Transmission Approach. In this approach the teacher is communicating maximum information to the students in minimum of time. This approach helps the teacher to cover the content to be taught to the students. This approach is widely used across all the subjects and different levels of education by the teacher. The main proponent of this method is David P. Ausubel. The word expository is derived from exposition which means an explanation or interpretation in which commentary by the teacher is given that seeks to clarify the meaning of and implications of the object of exposition. In this approach there are various methods such as Expository Method, Tell and do method, deductive method etc. are included. The approach is totally teacher centered. In this section you will be studying Expository method in detail.

Expository Method: If the initial move of the teacher is the statement of the rule or generalization or principle (followed by clarification, justification and application of the rule) then the sequence of moves is known as Expository Method.

SR—CR—JR—AR.

Depending upon the combination of these moves and number of moves used by the teacher while teaching, the expository method takes different forms such as telling method, tell and do method, lecture method, and expository method. In order to be effective expository teacher the teachers must use all the four moves in a sequence that is mentioned above.

Let us study the following example where in expository method has been applied to a unit from VI standard Science.

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3.3.1 Statement of Rule

If two liquids mix very well with each other than the liquids are known as miscible liquids. If the two liquids do not mix well then the two liquids are known as immiscible liquids.

The teacher can make use of different media to show this rule to the students such as writing on the board or use of PPT slide or preparing a worksheet specially prepared by the teacher to record the data.

After introducing the rule to the students, the teacher will give different examples by demonstration of miscibility/immiscibility of two liquids. All the cues are provided by the teacher hence the observations also should be from the teacher only.

3.3.2 Clarification/Explanation of Rule

In order to clarify the rule to the students, the teacher will conduct the experiments to demonstrate miscibility-immiscibility of any two liquids. He will have to use a number of liquids to clarify the rule.

Materials Required

Test tubes, Liquids such as Water, Alcohol, Milk, Kerosene, Lemon Juice, Mustard oil, Vinegar, Coconut oil, Butter milk and many others.

Data sheet to record observations

Sr. No.	*Liquid 1.*	*Liquid 2*	*Observation as reported by the teacher*
1	Water	Milk	
2	Water	Kerosene	
3	Water	Alcohol	
4	Water	Mustard oil	
5	Water	Coconut oil	

Many examples need be used by the teacher.

The teacher should demonstrate a number of examples to clarify miscibility and immiscibility of two liquids. Each example should be related to the rule stated in the beginning. This will help the students to assimilate the rule meaningfully.

3.3.3 Justification of the Rule

This is the rare move used by the teacher in the classroom. The justification of the rule can be done by various techniques such as historical development of the rule, proving the rule by different methods, asking the students to perform the experiment and reporting of the observations. In this example, the teacher can justify by changing the sequence of the mixing the liquids. If liquid A is miscible with B then B is miscible with A.

3.3.4 Application of the Rule

a) The teacher can apply the rule to more than two liquids

b) If A is miscible with B, B is miscible with C then A is miscible with C.

c) What would have happened if milk would not have miscible with water?

d) What would have happened if kerosene would not have miscible with diesel/if petrol?

Every time the teacher will relate to rule that is stated in the beginning. Ausubel has termed it as an Advance Organizer. This advance organizer is differentiated in terms of examples. Every time examples are anchored with Advance organizer, resulting in to Meaningful Verbal Learning.

3.3.5 Advantages

This is mostly preferred method/approach by the teacher all over the world. This method has definite advantages over two other approaches. These are given below.

- Effective in communicating new knowledge in short period of time. The teachers always complain shortage of time to complete the syllabus. If this method is judiciously used the teacher can 'Cover' the syllabus.
- Gestaltic view of the subject is presented to the students resulting into meaningful verbal learning.
- Effective for knowledge and comprehension objectives. There is no conclusive proof.
- Suitable for all types of subject matter and high levels of education. Hence it is still used to large extent at all levels.

3.3.6 Limitations

Although this is widely used approach/method, it suffers from the following limitations.

- Students are passive to a large extent. All the cues provided by the teacher.
- Rote memorization is encouraged.
- Not effective for higher level of objectives especially analysis, evaluation and creativity.

- Students depend on teacher all the time.
- No scope for the creativity of the students.
- Not at all suitable at lower level (Elementary and secondary)

In order to be effective transmitter of information/knowledge, the teacher should make all the four moves while teaching in the classroom. He/she will have to use first move as statement of the rule.

ACTIVITY -1

You know there are three types of substances- Acidic, Basic, and Neutral. Select any rule and draft a plan to teach that rule by Expository Method as explained in the preceding section.

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3.4 DISCOVERY APPROACHES

The main proponents of this category of methods are Jerome Bruner, Hilda Taba, Robert Davies and many others. Warren Colburn published a book entitled "First Lessons Intellectual Arithmetic upon the Inductive Method of Instruction". Since then a number of educators trying to popularize these group methods, but this method is rarely used by the teachers in the classroom. According to Bruner, discovery is a process, a way of approaching problems rather than a product or a particular item of knowledge. Many educators developed instructional strategies based on ideas proposed by Bruner.

The discovery approach is a type of teaching that encourages students to take a more active role in their learning process by answering a series of questions or solving problems designed to introduce a general concept (Mayer 2003). While teaching any rule from any discipline, the same moves are to be used as given in the Expository method but its sequence is different while using the discovery approach. There are three types of methods that are included under discovery approach- Open Discovery method, Guided Discovery method, and Deductive discovery method. The first two types Open Discovery and Guided Discovery methods are based on Inductive thinking and Deductive Discovery based on Deductive Thinking. Open Discovery method is mostly followed by Scientists where as the teachers use Guided Discovery method while teaching to the students. The pattern that is used in Guided Discovery method is

Notes

Example-Rule. The teacher starts with the examples of the rule and then the students generate rule on the basis of similarities and difference between different examples presented to them by the teacher. In this section Guided Discovery Method is explained in detail.

Since the moves used in the discovery approach are the same as those used in the expository approach, the distinguishing factor between the two is the position of the assertion move or statement of rule move. Hence guided discovery method can be defined as a sequence of moves in which the assertion move, if at all appears, appears late in the sequence. The typical sequence is as under:

CR—JR—SR—AR

Let us study this method by taking the same unit of Miscibility and Immiscibility of liquids. In this method the teacher does not state the rule in the beginning but starts with the examples of the rule as follows-

3.4.1 Clarification of the Rule

At this stage the teacher will make available all the material required for conducting the experiment related to miscibility/immiscibility of two liquids. The teacher should provide data sheet where in the students are required to record the data/observations of the experiment.

Materials Required

Test tubes, Liquids such as Water, Alcohol, Milk, kerosene, lemon juice, Mustard oil, Vinegar, Coconut oil, Butter milk and many others.

The teacher will start demonstrating experiment related to mixing of two liquids. Here is one more option available to the teacher as providing experimental kits to each student asking the students to write their observations in the data sheet.

Table 4.3 Data sheet for recording observations.

Sr. No.	*Liquid 1.*	*Liquid 2*	*Observations by Students*
1	Water	Milk	
2	Water	Kerosene	
3	Water	Alcohol	
4	Water	Mustard oil	
5	Water	Coconut oil	

Students are free to select any two liquids provided they do not choose harmful liquids such as Concentrated Sulphuric acid. The students should classify miscible and immiscible liquids in the context of Water.

3.4.2 Justification of the Rule

This is the rare move used by the teacher in the classroom. The students should be encouraged by the teacher to justify by changing the sequence of the mixing the liquids. The students should generalize as if liquid A is miscible with B then B is miscible with A.

3.4.3 Statement of the Rule

Through interaction between the teacher and the students, the students will generate the rule related to miscibility and immiscibility of two or more liquids. The teacher should help the students to verbalize the rule.

3.4.4 Application of the Rule

The items which have been given in Expository method can be dealt in discovery method also. The difference is that the students should do the experiment first and then based on observation the students can generate rules.

a) The students can take more than two liquids and mix with each other and observe.

b) The students mixes A with B, B with C and A with C then generate rule.

The students can discuss in small groups the following questions and report in the class.

a) What would have happened if milk would not have miscible with water?

b) What would have happened if kerosene would not have miscible with diesel/ petrol?

The example given above is of Guided discovery method. Some cues have been provided but the thrust is always from example to rule and that too rule is to be generated by the students.

3.4.5 Advantages

Since the students are involved in the teaching-learning process this method has certain advantages which are given below.

a) Process of teaching is more important than product of teaching. This creates interest among the students with respect o the subject of study. All the time the students may not be able to generate rule and put it in verbal form. In the beginning of discovery lesson the teacher should help in developing rule. As students exposed to such lessons they will learn to generate rules very easily.

b) Ability to analyze, organize knowledge in attacking problems is developed because students are actively involved in all the learning experiences created by the teacher.

c) Students enjoy learning because they themselves discover knowledge.

d) There is always constant interaction between content, teacher and the students. This results into development of information processing abilities of the students.

3.4.6 Limitations

Although the teacher is moderately monitoring the teaching learning process, if it is not properly handled then it may lead to the following limitations.

a) Time consuming; students may not progress beyond basic notions in any discipline.

b) Frustration may be there with low ability students because they may not discover any relationship.

c) A lot of efforts should be put in by the students and the teacher. The school should have enough resources to be provided to the students.

d) All teachers may not be comfortable with this method.

e) Costly method in terms of time and other resources.

It is generally found that teaching by discovery is more effective for achieving higher level objectives, and retention of the content taught by Guided Discovery Method than that of Expository Method.

ACTIVITY -2

The rule that is selected in the preceding section. Plan the teaching episode by guided discovery method. Use the space given below to write your plan.

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....

....

3.5 INQUIRY APPROACHES OR PROCESS SKILLS

There are number of inquiry approaches suggested by different experts. The common element in all these approaches is that the process skills are developed of the students when this approach is judiciously used by the teacher. This approach is proposed by Richard Suchman, Oliver and Shaver, Schwab, among others .The Inquiry Approach is the extension of the discovery approach. In any inquiry discovery is always there but vice versa is not true. In this method cause and effect relationship is established and the teacher provides no cues to the students. This is truly learner centered method. In this method teacher presents the students a problem/discrepant event to solve. Then the students ask questions to the teacher and collect the data. Then the students test the different hypotheses and finally find the satisfactory explanation to the discrepant event.

The typical sequence is as under:

CR—JR—SR—AR.

Although the sequence of Discovery and Inquiry is the same, the students ask questions to the teacher to collect the data related to a discrepant event presented by the teacher in the initial stages of the teaching episode. The following method is based on Inquiry Training Model proposed by Joyce and Well (1985). The ground rules for asking questions are as follows-

- Questions should be phrased so as to answer by 'yes' or 'no'.
- Once called upon student can ask as many questions as he may wishes.
- The teacher does not answer 'yes' or 'no' of theory verifying questions.
- Any student can test any theory at any time. Any time if the students feel to confer, they can do it.
- Inquirers are allowed to work with experimental kits.

Inquiry training has following phases.

i. Encounter with the problem.

ii. Data Gathering- verification.

iii. Data gathering—Experimentation.

iv. Hypothesizing.

v. Testing of hypothesis /Formulation of an explanation.

vi. Analysis of the inquiry process.

Discrepant Event / Problem for inquiry-

The first step in Inquiry Training model is the teacher demonstrates the experiment to all the students.

The teacher takes 20 cc of one liquid in one of the test tube and it was mixed in 20 cc of another liquid.

The teacher measures the volume of the resultant mixture of two liquids which is less than 40 cc.

The teacher asks the questions to the students.-Why the volume of the mixture did is less than 40 cc?

Table 4.4 Showing types of questions can be asked during inquiry training model.

Types of data	Type of questions	Verification	Experimental	Synthesis	Necessity
Objects Properties Events Conditions					

The students can questions to verify objects, events, properties and conditions with respect to verification, experiments and necessity. In all there are sixteen types of questions that can be asked with respect to any discrepant event or problem. It is generally observed that in the first encounter with this approach the students may not be able to ask 16 types of questions mentioned in the table. But once the students are exposed to this approach/method they ask different types of questions. A sample of 16 types of questions is given in the next section.

3.5.1 Clarification of the Rule

After observing the discrepant event demonstrated by the teacher, the students are allowed to ask the questions as they like so that they will collect the data with respect to the discrepant event. Examples of each of the sixteen types of questions are given below:

Verifying objects	Teacher's Response
Is it water as one of the two liquids?	Yes
Is it kerosene the other liquid?	No
Verifying events	
Does it happen with any two liquids?	No
Is it peculiar phenomenon with respect to these two liquids?	Yes
Verifying properties	
Does the first liquid evaporate quickly?	No
Does second liquid evaporate quickly in comparison with first liquid?	Yes
Was there any leakage in the third test tube?	No

Verifying conditions.

Does this reduction of volume happen at room temperature? Yes

Does it happen when glass test tubes are taken? No

Was there any liquid left in any one of the test tube? No

Once the students are familiar with this method they start asking experimental questions with respect to the problem/discrepant event.

Experimental Questions- Objects.

If we change from glass test tube to metal tubes, does volume get reduced? Yes

If we add colour to both the liquids, do we get same result? Yes

Experimental Questions- events

If we take 40cc of both the liquids, do we get volume less than 80cc? Yes.

If we change the experimenter do we get the same result? Yes

Experimental questions- properties

If we take 40 degrees Celsius temperature of both the liquids, do we get same result? Yes

If one of the liquid is not mixable, then do we get the same result? No

Experimental questions- conditions

If we mix second liquid to first liquid, do we get same result? Yes

If we perform the experiment in the open air, do we get the same result? Yes

Synthesis –objects

Does this phenomenon happen with water and alcohol? Yes

At this point the students discover that 20 cc of water When mixed with 22 cc of alcohol, the resulting volume is less than 40 cc. But inquiry goes beyond discovery. Why the volume is decreased is further explored by the students through questioning.

Does this phenomenon depend on type of test tubes, experimenter? No

Synthesis Questions - Events

Does the reduction in volume due to miscibility of two liquids? Yes.

Notes

Does the reduction in volume due to evaporation of one of the liquids? No.

Synthesis Questions- Properties

Does reduction in volume is due to miscibility of water and alcohol? Yes

Does reduction in volume is due to difference in sizes of the test tube? No

Synthesis questions –conditions.

Does reduction in volume is due to conduct of the experiment at normal temperature? Yes.

Does reduction in volume is due to error in measurement? No

Necessity Questions- Objects.

Is it necessary to use the two liquids to observe this phenomenon of reduction in volume? No.

Is it necessary that only water and alcohol should be used? Yes.

Necessity Questions Events

Is it necessary alcohol should be added to water in order to observe the phenomenon? No

Is it necessary to use same measuring cylinder for finding out volumes? Yes.

Necessity Questions Properties

Is it necessary both the substances in liquid form? Yes.

Is it necessary that both the liquids should be colourless? No.

Necessity Questions- Conditions

Is it necessary that both the liquids mixed together at the same time? No.

Is it necessary to repeat the experiment several times to arrive at conclusion? No.

The various types of questions that can be asked have been given above. The students may not be able ask so many different types of questions in the beginning but with repeated use of this method gradually start asking number of different types of questions. The questions may not appear sequentially. The process is more important than finding out satisfactory answer to the discrepant event. With the help of questioning the students may arrive at satisfactory solution to the discrepant event.

3.5.2 Justification of the Rule

This is the rare move used by the teacher in the classroom. The students should be encouraged by the teacher to justify by changing the sequence of the mixing the liquids. The reduction in volume takes place irrespective of order of mixing the two liquids.

3.5.3 Statement of the Rule

Through interaction between the teacher and the students, the students will generate the satisfactory explanation why there is reduction in the volume when alcohol and water are mixed together.

3.5.4 Application of the Rule

The rule/scientific principle can be applied to other fields also. It has been observed that the students actually applied this principle to different fields. The items which have been given in Expository method and discovery method, these can be used in Inquiry method also. The difference is that the students should do the experiment first and then based on observation the students can generate rules.

a) The students can take more than two liquids and mix with each other and observe.

b) The students mixes A with B, B with C and A with C then generate rule.

The students can discuss in small groups the following questions and report in the class.

c) What would have happened if milk would not have miscible with water?

d) What would have happened if kerosene would not have miscible with diesel/ petrol?

3.5.5 Advantages

This is most effective method from the students' point of view. They control the teaching learning process all the time. The advantages of this method are as under.

a) Thought provoking method. Divergent type of thinking is encouraged and nurtured. This is reflected in different types of questions that are asked by the students during data gathering phase.

b) Development of the inquiry processes of the students. The process consists of collection of the data, formation of hypotheses, testing of hypotheses and ultimately formulation of satisfactory explanation of discrepant event/problem.

c) Learning becomes challenging and joyful.

d) Students become independent learners. Develops scientific outlook.

e) Students realize the tentative nature of the knowledge. A particular theory may be modified subsequently leading to more satisfactory explanation.

f) Cause and effect relationship is established. This is required for development of theory from that area of specialization.

3.5.6 Limitations

This method is quite modern in comparison with earlier methods. It has the following limitations.

a) Time consuming. When the students are exposed to this method first time they are not able to ask precise questions. This result in to delay in finding out solution to the given problem.

b) All the units cannot be taught by this method. It can be applied to the situation where cause and effect relationship is to be established

c) The students may get frustrated if there is no satisfactory explanation is reached.

ACTIVITY -3

1. *The different questions related to discrepant have been given in the preceding section. Write down at least one question under each of the categories of questions.*

   ....

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   ....

2. *Develop discrepant/problems to be solved by Inquiry method.*

   ....

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   ....

3.6 LET US SUM UP

It is clear from the above discussion that the methods are not mutually exclusive but they differ in the sequence of moves. Although the sequence in discovery and inquiry is the same, they differ in with respect to the clarification move. In inquiry the students ask questions to the teacher related to the discrepant event and collect the data. This is part of the clarification move. By using these methods judiciously in an eclectic manner the following transformation takes place in the classroom which is experienced by the author.

Lower level objective — Higher level objectives

Monologue—Dialogue — Interaction between the students.

Content knowledge — Syntactic knowledge.

Knowledge as a product — Knowledge as a process.

Convergent thinking — Divergent Thinking.

Memorization — Mastery Learning.

Teacher centred — Student centred

It is experience of the author that the teachers can be trained to use all these methods comfortably and can be applied in any classroom irrespective of the number of students in the classroom, the subject taught, and grade level of the students. The author is of the opinion that there a few units of teaching which can be taught by either by discovery or by inquiry. If the teachers spend about 15% to 20% of the total teaching time on these two methods it will make our classroom more enjoyable and vibrant. And ultimately the statement made in the report of the education commission by prof. Kothari, 'The destiny of India being shaped in her classroom' will come true.

APPENDIX

In the section 4.5 Inquiry Training Model has been explained briefly. Some of the examples of the discrepant events are given below. You as a teacher can yourself find out the discrepancy.

i) Materials. - Rubber band, weights. Suspend the weight by the rubber band. Put the lighted match near the rubber band. The weight will rise. Why the weight rises when rubber band is heated?

ii) Materials- Matches, piece of cotton cloth, rubbing alcohol, and water. Soak the cloth in a mixture of 2 parts of alcohol and 1 part of water. When lit the alcohol will flame up and burn, but the cloth will not be consumed Why the cloth is not burnt although dipped into alcohol?

iii) An explorer walks one mile south, then walks 1 mile east, then turns and walks one mile due north. He finds himself back where he started. Why the explorer reached to the same point where he started?

iv) Carbon dioxide raw hide why decide tightly boxed Hold the glass rod over these words. Look through the glass rod. What do you observe? Why some words look exactly the same whereas some words differently?

v) Materials — Raw egg, large jar, vinegar. Place an egg in the jar full of vinegar and let the egg stand over night. The egg will rise to the surface, sink to the bottom and perhaps rise again. By morning the egg will be enlarged and have a soft shell. Why the egg is enlarged and become soft?

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3.8 UNIT-END EXERCISE

Assignment/Project

Shri Lawate is a secondary school teacher from a small town from the state of Maharashtra. He has evolved his style of teaching with the help of blending tenets of

Philosophical role model Experimentalism, and Psychological theories such as Constructivitism, and Humanism. He typically uses these tenets to teach a unit from Chemistry to the VII grade students as follows-

One day he started teaching unit by showing two test tubes half filled with two liquids. He asked the students about the colour of the two liquids which were colourless. Then he poured both the liquids in a beaker. The students were surprised to see the colour after mixing as beautiful 'PINK' colour. Then he threw the liquid on the students who were sitting just near to the teacher's table. Then the students started shouting saying that sir what are you doing? Is it holi?. There was dissonance in the class.

Today we will study why was there pink colour after mixing two liquids? And Why was colour faded away?

You can ask me as you can but I will answer by Yes or No. The students were exposed to Inquiry Training Model by the teacher. The students could arrive at explanation of the discrepant event.

Carefully study this learning scenario and complete the assignment with the help of following activities.

1. Prepare a plan based on four moves as SR, CR, JR and AR.
2. Implement the prepared plan in your classroom.
3. Audio record the lesson.
4. Transcript the lesson.
5. List down the different types questions asked by the student.
6. Prepare a report of your teaching-learning process.
7. Your suggestions to improve teaching.

UNIT 4 HANDS ON EXPERIENCE: ROLE AND IMPORTANCE

Structure

4.0 INTRODUCTION

You have already studied about the Nature of Science, Scientific Inquiry and different approaches to teaching Science in the previous units. Now you are going to learn about Hands on Experiences in science teaching - learning process.

According to, Mahatma Gandhi: "By education I mean an all - round drawing out of the best in child and man - body, mind and spirit." (That is education through and by, Hand, Head and Heart.)

Notes

John Dewey, "Education is reconstruction of experiences".

"The new philosophy of education is an experimental philosophy. All experiences cannot be educative. The traditional education gave pupils experiences but not of the right type. The business of the educator is to set a kind of experience which while being agreeable promotes having desirable future experiences. The centre problem of an educator based up on experience is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences. The continuity of experience is the philosophy of Educative Experiences. It is held that education is a development within, by, and for Experiences. Education is by, of, and for experiences. Thus an integrated personality exists only when successive experiences are integrated. This continuity and inter action provide the measure of the educative significance, and value of an experience." Now, what's your thinking about learning experiences?

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4.1 LEARNING OBJECTIVES

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

- explain the role of firsthand experience.
- describe the types of investigation.
- demonstrate the practical.
- discuss about safety measures.
- use types of experiences in teaching learning process.

4.2 ROLE AND IMPORTANCE OF HANDS ON EXPERIENCES

"No any mental activity will be completed without any physical activity."(Einstein)

We discussed about, what is Science? Scientific knowledge, Scientific Thinking, Scientific method, Importance of scientific inquiry, Scientific inquiry skills, and Different Approaches to Teaching Science. Now we are going to learn about, Role of firsthand experience in children's learning, Types of investigation: in class and out of school, Organizing practical work and safety measures; in and out of school.

Learning occurs when the pupil has an experience, that is, when he reacts to the situation in which he finds himself. Learning takes place by interaction between the situation and the learner. When any situation acts up on the learner, the learner reacts, modifies his behaviour and this interaction results in learning.

Consider the following examples:

- Child tries to put water from a glass into a bottle. He gains control over his muscles.
- Child burnt her fingers when she touched a hot pan on the gas. There is some interaction. Now she will not go near the pan or gas. Learning takes place through these experiences.
- Pupil sees a person slipping over a banana skin on the street. She will not step over a skin of banana in the street. She throws the skin of banana in a dust - bin. This experience has modified her behaviour.
- Children from Bhuj, Gujarat school experienced the tremors of an earthquake. They learnt how to face a calamity. This experience helped them modify their behavior.
- A boy from the slum area observes that elderly persons abuse one another even with a slight instigation in everyday life. He reacts to the situation and picks up the same style. He has learnt though not in a desired direction.
- Geeta participate in the school tournaments. She was cheered - up by all when she won a prize. The experience modified her behaviour. She developed confidence and she pursued these activities further.

Write down the list of learning experiences from the above examples.

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It is clear from these examples that a child is exposed to various situations in life. Every experience has its own impact on the child, who in turn reacts. This interaction results in learning which is seen through modification of the behavior.

Experiencing is simply seeing, hearing, feeling, tasting, and smelling and so on. The individual reacts to these experiences and learning takes place. We learn because things happen to us and we do something in turn. It is only through experience that we learn. Learning will not take place in the absence of any experiences. The phrase *learning experience* is probably a tautology. All experiences are learning experiences.

Which sensory organs are used in the above learning experiences?

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Child is learning every movement, because of varied experiences he is getting in the life. The learning process becomes synonymous with memorization and factual information becomes the learning product. But learning does not mean only memorization. It is defined as the process of acquiring knowledge, abilities, skills, attitude, and so on which are exhibited through behaviours (cognitive, affective and psychomotor). These are the learning outcomes. Quality of experiences which the children have, will determine the quality of learning.

4.2.1 Role and Importance of Hands on Experience

The mediocre teacher tells.

The good teacher explains.

The superior teacher demonstrates.

The great teacher inspires. - William A. Ward

- *You cannot teach a man anything; you can only help him find it within himself.*- Galileo
- *Teach only when cornered, otherwise let the people learn.*- Keith King

Children learn by thinking, feeling and doing. Learning results from the active participation of the pupil. Teacher creates different stimulus situation in the class. It is the interaction of the learner with the situation, created by the teacher, enables learning. Each of these situation helps to modify the behaviour of the pupil.

Learning experiences can be of different types. One significant method is 'hands on experience'. It is also known as learning by doing. In hands on experience learner gets an opportunity to handle, say, equipment, instruments, and other such materials by him or herself e.g. Playing Tabla demands hands on experiences. Similarly, students can separate the mixtures practically. Sowing the seeds, watering the plants or few others examples. It may not be possible to teach all topics / concepts using hands on approach. However, in science teaching learning process many concepts can be taught using hands on experiences. It is for the teacher to think and device possible and relevant activities / experiments for students' hands on learning. At the same time it is important to consider all the safety measures connected to the activities. It is also advisable to take care of multi-sensory approach that is the activities' included for hands on experience may include seeing, listen, assembling , fixing , moving, etc. this kinds of hands on approach in learning helps in easy learning , practical learning and permanent learning. Thus it is important to understand the roll of senses in learning.

ACTIVITY-1

List five possible hands on activities for different concepts in science subject?

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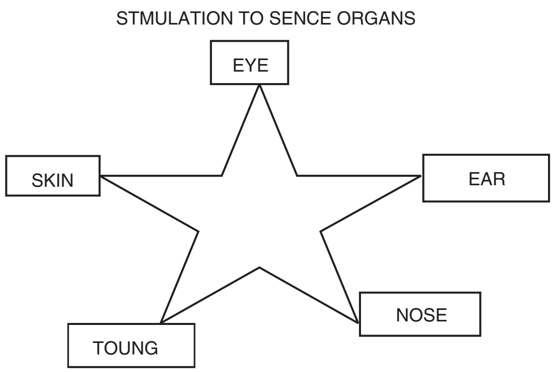


When you arrange the proper stimulation for different sense organs, then learning becomes fruitful. Multi-sensory learning always benefits the learner. Therefore teachers are expected to use different teaching aids and activities

4.2.2 Make Use of Senses

Senses are the get ways of knowledge. The success in teaching lies in the maximum use of the different senses. Out of the five senses - Sight, Hearing, Feeling or Touch, Smell and Taste, the first three are most important in learning. The senses of smell and touch also used in learning many things but are comparatively less used in learning science and technical subjects. How much do we learn through the different senses is clear from the following chart:

Table-1: Percentage of learning through different senses

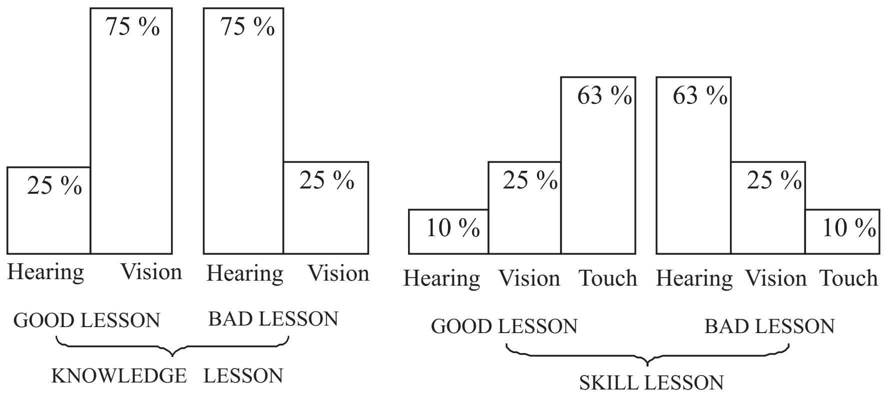
Senses / *Objectives*	*Vision*	*Hearing*	*Touch*	*Smell and Taste*
Knowledge	75	25	–	Used only in some subjects such as identification of chemicals, sanitation, cookery etc.
Skill 25	10	65		

It is clear from the above table that in teaching science effectively the sense of hearing (lecturer, discussion, question-answer etc.) has comparatively little place. The sense of vision (demonstration, charts, models, computer based teaching etc.) should be used. The effectiveness of the lesson is determined by the proportionate weightage given to each of the three main senses. A good and bad lesson can be judged by the distribution of time to each sense. This may be clear from the following graph.

Lecture, explanation, discussion etc. (HEARING)

Demonstrations, charts, models, Computer based, other audio-visual aids (VISION)

Practice by students, Physical participation of the students (TOUCH)



An effective lesson in science should emphasize on hands on experiences in teaching learning process, wherever possible. Demonstrations, practical work and activity by the students are some of the examples which use the sense of vision, hearing and touch.

4.3 ROLE OF FIRST HAND EXPERIENCES IN CHILDREN'S LEARNING

In the process of learning child not only uses the cognitive domain but also psychomotor and affective domains when somebody makes use of multiple sense organs as receiver of stimuli s/he gets better chances to develop conceptual clarity. Use of body parts enhances skill and formulate attitude which is possible only through first hand experiences. Because of use of more number of sense organs learning experiences get concretised experiences of different types make learning comparatively permanent.

4.3.1 Classification of Experiences

Learning experiences can be classified as direct and indirect experiences.

1. **Direct Experiences:** This refers to learning activity that involves firsthand experience with various objects or symbols. It includes what is commonly referred to as perceptual learning, but it is a broader term since it includes experiences with symbols such as used in science. Perceptual learning applies to experiences dependent upon seeing, hearing, tasting, smelling, touching, handling and manipulating things in different ways. When we use such term as sweet-bitter, soft-hard, tall-short, smooth-rough, we get the meaning through perceptual learning. We can then use these symbolic words for describing various things.

   Following are illustrations of direct experiences or hands on experiences:

   i. Observing and experimenting with materials and apparatus.

   ii. Constructing models, plans, charts etc.

   iii. Drawing a description either orally or in writing.

   iv. Presenting a description either orally or in writing.

   v. Summarizing, stating generalizations etc.

   vi. Listing important facts, points and so on.

2. **Indirect Experiences:** This is the type of experience through which we acquire the learning outcomes without firsthand experience. It makes use of direct experience of others. We learn much through the experience of others. These experiences include such activities as reading, looking at pictures, listening to lectures and discussions and so forth. Such learning activities are very important since it is impossible for us to have all firsthand experiences. You can enjoy the thrill of mountaineering by listening to a talk of a mountaineer and field visits, excursion etc.

   Following are illustrations of indirect experiences of hands on experiences:

   i. Reading or discussion in books, magazines, papers etc.

   ii. Listening to oral discussions, lectures and so on.

   iii. Observing pictures, maps, charts, models etc.

It is obvious that in practical learning situations, we cannot completely separate the activities according to these two types, nor is it desire to do so. There will be a combination of direct and indirect experiences in many of the activities.

- **Importance of learning experiences:**

   a) Direct experiences are most effective but we can't give it always to students like, earthquake, war, flood etc.

b) Many times a teacher can create live picture of the things, with his imagination and explain it very effectively. It is more effective than direct experiences even at times.

c) For the day-to-day teaching indirect experiences are more practically applicable.

d) By observing indirect experiences you can teach effectively.

e) Verbal experiences play an important role in teaching learning process, if they are used effectively.

4.3.2 Criteria for Choosing Hands on Experience

a. It should be directly related to the instructional objective.

b. It should be related to life-situations.

c. It should be appropriate to the maturity level of the learner.

d. While selecting the experience, availability of material and time should be considered.

e. It should be varied and rich in content.

While selecting any hands on experience, the teacher must see that it leads to the attainment of any given educational objective. It is also possible that hands on experience may lead to the attainment of several objectives. Changes in pupil's knowledge, attitude and skills have to be brought about gradually. Learning experiences are not merely confined to the class-room. Teacher will have therefore to use various teaching devices for providing suitable hands on experiences. Following are some of these:

I. **Experiments:** they provide learning experiences to achieve objective such as skill in handling apparatus, observation and understanding etc. skill related objectives.

II. **Audio-Visual Aids:** Radio, films, filmstrips, epidiascope, OHP, slide projector, computer assisted teaching, with the help of mass media, NET / WEB / YouTube based teaching, etc.

III. **Activities based teaching:** Dramatization, debating, various curriculums based competitions etc.

We shall now consider hands on experiences pertaining to **Science subject.** Science teacher will have to use demonstration, experimentation, and observation for giving necessary learning experiences in the teaching of science. The list given here is only illustrative; you may add more to it.

a) Demonstrating experiments in the class-room and laboratories for encouraging students to observe and derive conclusions.

b) Students to perform experiments themselves.

c) Allowing students to handle apparatus, to locate the defects if any and set it in order.

d) Developing a museum with the help of students.

e) Developing medicine, botanical, butterfly garden with the help of the students.

f) Encouraging students to maintain records of various observation like- plant growth, day-to-day temperature, misuse of water and electricity, birds, animals etc.

g) Encouraging students to find out causes-and-effect relationship in day-to-day situations, developing scientific attitude through discussion and experimentation.

h) Observing the stars and planets at night.

i) Visit to planetarium.

j) Conduct the science-club activities.

k) Preservation of energy resources like- water, electricity, plants etc.

ACTIVITY -2

Give the answer to the following:

1. *List the learning experiences from any topic of your choice from class VI Science text book*

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2. Illustrate any one of the listed experiences in out of school situation.

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3. *State the various characteristics of the good learning experiences.*

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4.4 TYPES OF INVESTIGATION: IN CLASS AND OUT OF SCHOOL

Students must have studied some science before entry into initial teacher training; they are frequently challenged by the requirement to work on open-ended investigations with young children. Early in their course they begin to address this problem by engaging in a simple group investigation in class. Then they carry out an individual one at home, which is reported in a written assignment.

What are investigations?

Whereas, according to the Concise Oxford Dictionary (Allen, 1991), the word *investigate* has the broad meaning "to enquire into; to study carefully", in current science education literature the word *investigation* has become more focused. Thus, the National Curriculum for England (DFEE/QAA, 1999) identifies ten investigative skills which children should be taught in the context of "collecting evidence by making observations and measurements when trying to answer a question" (DFEE/QAA, 1999: 16). These skills involve planning a fair test, obtaining and presenting evidence, and evaluating the outcome. Furthermore, science investigations are regarded as involving more than practical activities. They incorporate the use of concepts and cognitive processes as well. Investigations are not the only type of practical work to be found in science lessons. For example, Gott and Duggan (1995) identify three others:

- Acquiring a practical skill, such as using a thermometer,
- Observing objects and events which can be related to scientific ideas,
- Discovering or illustrating a scientific concept, law or principle.

The purpose of investigations in the curriculum

The rationale for incorporating investigations into science lessons in the 1960s and '70s reflected the heuristic approach to learning. The pupil was trained to find things out for him/herself, based on a belief in the effectiveness of learning through action as opposed to the passive assimilation of knowledge. However, the heuristic view of learning has fallen out of favour since the realization that pupils need input from their teachers as well as practical experiences. They cannot be expected to 'discover' complex scientific ideas for themselves without guidance (Gott and Duggan, 1995).

Another purpose for investigations is seen in the constructivist view of learning, where pupils are believed to correct mistaken ideas in response to cognitive conflict (Piaget, 1969). If taught within a constructivist framework pupils will be encouraged to express their ideas, about objects, events and then to test them through investigations with the help of hands on experiences. It is hoped that pupils will modify their misconceptions in the light of the empirical evidence produced (Jarvis et al., 2001).

The purpose for investigations is the belief that they will help develop scientific literacy. By engaging in processes similar to those of professional scientists pupils will be better able to understand how science knowledge is created and to take part in debate about scientific issues. However, Jenkins (1996) suggests that the idea that first-hand experience of investigations will develop pupils' understanding of the nature of science is problematic and contentious, while Donelly (2001: 181) notes that "the phrase 'the nature of science', unless carefully qualified, suggests that science can be characterized in some unitary and integrated way". Jenkins argues that "as a component of school science education, it is marked by a variety of broad interpretations, some of which are mutually contradictory and by a diversity of rationales" (Jenkins 1996).

Types of investigations: Identifying different kinds of investigations and describing their features, is not a simple task. The following list of different kinds of investigations has been developed more from our information about the work that goes on in schools, rather than an attempt to define the investigative work done by 'real' scientists. It also relates to the structure of the investigation rather than any pedagogical considerations, such as whether the investigation is open or closed whether it is a part or whole investigation or whether it is an individual or group investigation.

1. Fair testing
2. Classifying and Identifying
3. Pattern-seeking
4. Exploring
5. Investigating Models
6. Making Things or Developing Systems

1. **Fair testing:** These investigations are concerned with observing and exploring relations between variables. Systematic changes in the independent variable are compared with changes in the outcome, or dependent, variable. The emphasis in such investigations is for pupils to identify one (or more) independent variable(s) to be manipulated independently of other factors. Pupils must then control the other factors, for a 'fair test'.

   Examples:

   What affects the rate at which sugar dissolves in water?

   What makes a difference to the time it takes for a paper spinner to fall?

   Which is the strongest paper bag?

2. **Classifying and Identifying:** Classifying is a process of arranging a large range of phenomena, into manageable sets; identifying is a process of recognizing objects and events as members of particular sets, possibly new and unique sets, and

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allocating names to them. Classification and identification both involve pupils identifying features, tests or procedures that discriminate between things or processes that are being studied e.g. patterns in chemical and physical properties of chemicals that allows classes of chemicals to be differentiated from one another.

Examples:

What is this chemical?

How can we group these invertebrates?

3. **Pattern-seeking:** These investigations involve observing and recording natural phenomena or carrying out surveys and then seeking patterns in their findings. They have many similarities to Fair Testing investigations but have three significant differences. Firstly, because they are dealing with natural systems, pupils cannot manipulate or control variables as easily. Secondly, pupils initiate the investigation differently: they notice an effect, or the dependent variable first e.g. the dandelions near the hedge seem to have longer leaves than those away from the hedge, and then structure the investigation around finding a possible cause for the effect. Finally, they have to take into account the increased importance of selecting a suitable sample size in order to account for natural variation within samples.

   Examples:

   Do dandelions (*dudal* or *kanphul*) in the shade have longer leaves than those in the light?

   Where do we find most snails?

   Do people with longer legs jump higher?

   What caused the outbreak of salmonella (A bacteria which cause food poisoning)? [Using secondary sources]

4. **Exploring:** Pupils either make careful observations of objects or events, or make a series of observations of a natural phenomenon occurring over time. As they carry out their observations, they make decisions about what exactly to observe and the number and frequency of observations. Not all explorations are scientific. What determines whether an exploration is scientific is its purpose.

   Examples:

   How does frog-spawn develop over time?

   What happens when different liquids are added together?

5. **Investigating Models:** A fifth category of investigations contains investigations that explore models. This category is distinct from the previous four categories in that it incorporates a stage where pupils have to decide what evidence should be collected in order to test a model. Testing models may lead on to one or all of the preceding types of investigations, but which approach is chosen depends on the decisions made about what would count as evidence to test the model. For example, some pupils may have a model of heat as 'stuff' which would pass more easily through insulating materials with large gaps between the particles; others may have a model of heat as a transfer of energy of the particles themselves which would occur more easily if the particles of the insulating materials were closer together. Carrying out a fair test into the insulation properties of different materials will help pupils test their models against evidence. The process of testing models can give pupils an insight into the relationship between evidence and scientific models in a way that other kinds of investigations often do not.

   Examples:

   How does cooling take place through insulating materials?

   Does the mass of a substance increase, or decrease, during combustion?

6. **Making Things or Developing Systems:** These investigations are usually technological in nature, where pupils design an artifact or system to meet a human need. Only those investigations that have a high scientific knowledge and understanding component, such as knowing that a complete circuit is needed to make an electrical device work, can be categorized as scientific investigations.

   Examples:

   Can you find a way to design a pressure pad switch for a burglar alarm?

   How could you make a weighing machine out of elastic bands?

   The teachers recognized that any investigation could be carried out in a non-investigative way, for example: teachers telling their pupils exactly what to do at every stage of the lesson. They identified two defining characteristics of investigative science.

   Firstly, in an investigative work, pupils have to make their own decisions. They must be given some autonomy in how the investigation is carried out, although the amount of autonomy given may vary at different stages of the investigative process.

   Secondly, an investigation must involve pupils in using some investigational procedures such as planning investigations, measuring, observing, analyzing data and evaluating; they recognized that no investigation will allow pupils to use every kind of investigational procedure.

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ACTIVITY -3

Question: Try to follow above or similar situations and let students get response. Let them prepare the record of their answers.

What is this chemical?

How can we group these invertebrates?

What affects the rate at which sugar dissolves?

Do dandelions have longer leaves in the shade than in the light?

Where do we find most snails?

How does frog-spawn develop overtime?

What happens when different liquids are added together?

How does cooling take place through insulating material?

How can the movement of a trolley be modeled?

How could you make a weighing machine out of elastic bands?

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4.5 ORGANISING PRACTICAL WORKS

'*Learning by doing*' is one of the cardinal principles of teaching science. In order to make the practical work most effective, the science teacher should always keep in view the following points:

The Classroom Environment

Virtually all of us have little or control over how many students we must teach. However, we do have control over the classroom environment in which they learn. This is very important, since this environment affects how well your students can learn. Close your eyes and imagine yourself as a new teacher who is assigned to teach a class containing 60 or more students. After the initial shock, or maybe in response to it, what questions might you ask yourself? Most likely the first question that would come to mind is "How am I going to manage them all?" Actually, this question highlights one of the most critical aspects of working in large classes, namely, managing the classroom's environment so that it is a comfortable space in which to teach and learn. The classroom environment encompasses the physical environment – including learning resources for lessons – as well as the psycho-social environment; for instance, using ways to promote learning as a community to reduce the feeling of crowdedness and to deal effectively with misbehaviour. Your ability to create well-managed physical and psycho-social environments can make the difference between a calm and functioning classroom.

Organizing the Physical Environment

Ideally, a class is held in a bright, clean, well-equipped room that accommodates every student comfortably and allows them to move around and work well either individually or in groups. To encourage active learning and student involvement, seats are arranged so students can see each other as well as the teacher. Unfortunately, very few classrooms are ideal settings for learning and, especially in large classes, space is usually limited. Often hot, crowded, and noisy, small classrooms overflowing with many students Practical Tips for Teaching Large Classes offer a poor learning setting for you and your students. You will need all of your ingenuity and planning skills to create a classroom that is a comfortable place in which to learn. But your hard work will be worthwhile, since it will make your job easier and more rewarding. Below are some areas associated with the classroom's physical environment that you might consider as you plan on how to accommodate all of your students and reduce feelings of crowdedness, confusion, and frustration that often plague large classes.

Maximize classroom space

While many of us don't have control over where we teach, we may have the opportunity to arrange our assigned classroom as we see fit. The arrangement of a classroom may be flexible or a challenge, but the idea is to draw students into the group and to create a physical space that makes them comfortable and want to enter into a discussion or group situation. In large class settings, space is often a luxury. To maximize what learning space is available, consider removing unnecessary furniture to reduce the feeling of overcrowding and to facilitate movement. If you really don't need a large teacher's desk, ask for a small one. Instead of desks or chairs for students, consider using mats or rugs with your students being seated so that everyone sees each other and feels a part of the group. A large learning space, covered with a clean, locally made carpet or mat, can be easily changed from a science investigation space to a drama space, and groups can easily be formed and reformed without disturbing other classes. Several chalkboards may also be found around the classroom at the children's level, so that they can sit in groups and use the chalkboards for planning, discussing ideas, problem solving, etc.

Use space outside of the classroom

School grounds can be a rich resource for learning, and they can serve as an enjoyable complement to crowded classrooms. They are also important sites for students to develop both social and cognitive skills and to learn important lessons about cooperation,

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ownership, belonging, respect, and responsibility. Look around your school, identify good areas for learning, and incorporate them into your lesson plans. For instance, different areas of the school grounds can be used as activity centers to support what is being learned about a subject in the classroom. In learning about geometric shapes, for instance, students can explore the school grounds and identify as many geometrically-shaped objects as possible. Practical Tips for Teaching Large Classes can sit under a tree and write down as many as they are able to recall. Monitor their progress! Before class ends, bring them all together, either in the classroom or outside, to present their findings.

Display student work creatively

Space is needed to display student work. Rather than display boards or tables, which take up space, students' work can be hung on a classroom wall or displayed just outside the classroom door for everyone to see. Strings can be used onto which each student's work is attached with clips, tape, or even blunt thorns. Decorating the room with student work will also help add to the attractiveness of the room and make it more welcoming, even if there are a lot of students in it.

Building the Psycho-Social Environment

A classroom is often called a "learning community." It is that place within your school where you and your students can be found regularly, where everyone hopefully knows everyone else, and one in which everyone works together – teacher and students alike – to learn new things about the world.

4.5.1 Ten Practical Tips for Teaching Large Classes

1. **Know your students – match names with faces**: Although it may seem frightening in a large class setting, learning your students' names is the first step in creating a comfortable classroom that will encourage student participation. It also shows students that you are interested in them as individuals. Fortunately, there are many simple ways for learning students' names and getting to know them:

2. **Make a seating chart**: Ask students to sit in the same seats for the first few weeks and prepare a seating chart. Try to memorize as many names as you can from each class session.

3. **Take photographs or have students draw pictures**: If possible, group students for pictures during the first or second day of class. Posing for a picture often creates an informal, relaxed environment. Pass the photographs around and have students write their names next to their picture, or number each student and have them write their names at the bottom of the photograph next to their number. If photographs are not possible, have them draw pictures of themselves, or put

them in pairs and have them draw their partner. Encourage them to draw something unique about their partner, such as a missing tooth or curly hair, to help match pictures to faces. Add their names to the pictures, and place the pictures near where they sit. If it is not possible to put the pictures near the students, for the first week or two of school have your students sit in rows, if they are not doing so already (you can break them into learning groups later). Line up their pictures vertically on the wall next to each row, with the top picture being the student nearest the wall, and the bottom picture being the student furthest from the wall.

4. **Use name cards and tags**: If photographs or pictures are not possible, have students make name cards that they place in front of them during class. If you are not using desks, your students can make name tags to wear during the first few weeks of school. Before class, and during it, learn the names of students sitting along the aisles and call on them in class by name. Progressively work your way to the centre of the room, calling each student by name.

5. **Use positive discipline techniques**: Students in class will misbehave and violate rules, no matter if the class is large or small. It is a normal part of their development and not a reflection on you. When students misbehave, a teacher may use corporal punishment as a way to control the situation.

6. **Pay attention to students with more individualized needs**: Are there students in your classroom who will need extra help? What kind of support will you need to provide to these students? Do you need to help them on an individual basis, or can other students assist them? Do you need to make sure that they are sitting in an appropriate place in the classroom? Often it helps to have students who need extra help at the front of the classroom where you can easily help them, especially if your classroom is crowded.

7. **Develop, and follow, a formal lesson plan**: Good lesson plans achieve at least two objectives. First, they outline what the teacher hopes will occur during a class and, possibly more important, they convey to students that their teacher has thought about the session and its activities. Some of the ways you can plan your lessons well are by using a simple lesson planning outline, daily lesson planning format, or a lesson planning matrix as shown below.

   Sample Lesson Planning Matrix: Try to give specific format to the student for the practical work like below or any more as you know.

   Topic

   Objectives

   Teaching Methods

   Resources

   Classroom Arrangement

Learning Activities

Assessment

Reflection

8. **Plan/Budget your own time carefully**: Teaching a large class takes a great deal of time and energy. If you feel rushed or overwhelmed, your students will feel it too. Set up weekly work schedules for yourself so that you are prepared for what needs to be done. Find ways to scale back other obligations, if you can, so that you have time to deal with the complexities of teaching such classes.

9. **Other Active Learning Strategies:** There are many other active learning strategies that you can use in large classes. It depends up on yours direct or in direct experiences.

10. **Design assignments that reveal whether students can apply what they are learning to everyday situations, not simply just understand the process:** Give in-class exercises and out-of-class assignments to see if they have developed this ability. For instance, give them an assignment, either individually or in groups, to observe how mathematical concepts are used in a market or in building a house. These strategies will help you to check the accuracy of your students' thinking processes and analytical skills. Based on your assessment, you can then give them immediate feedback to improve their skills.

Remember: *Many students can solve a problem, but you should want them to know why they got a particular answer, not just how. This is the true proof of learning in any subject. Good teachers of large classes reflect on their teaching. They don't reflect on the problems of having many students in a classroom. It's a given fact, and nothing can usually be done about it. Instead, good teachers think about their teaching – all of it, their own classroom behaviour, the plans they have, the activities they use, the backgrounds and experiences of their students, what and if their students are learning, why and why not. And good teachers do more than think about their teaching; they use whatever means possible to improve upon it. Hopefully through this document, you have learned some valuable tips and suggestions about how to improve teaching and learning in your large class.*

ACTIVITY -4

1. *Which ideas do you want to try first?*

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2. *Conduct any one practical work within your school text book and write an ideal practical report on it.*

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4.6 SAFETY MEASURES: IN CLASS AND OUT OF SCHOOL

Children in elementary school are in their childhood stage. They do have little knowledge about the danger they are supposed to face while moving and playing in school premises. Parents have full confidence about the safety of their children in school. Teachers are responsible guide in the matter. Children need to be made aware of the problems they are supposed to face on the way to school, in the school premises such as playground, laboratory etc. and in the classroom from outside agencies as well as from the peer group. The preventive and remedial measures need to be known to them.

4.6.1 Creative Science Safety

The most important aspect in hands on experience is safety. Safety in respect of chemicals, fire, electricity, mechanical activity etc. hazards material should be kept away from the children and due care is required to prevent hurt injury accident etc. When you conduct creative activities, proper planning and preparation will assure you of a happy ending. Make sure that you:

a) Label all the bottle containers of materials unless the contents are visible and recognizable to all (like nuts and bolts). List on the label the contents and precautions to follow.

b) Try all equipment and materials yourself before using them in front of children.

c) Whenever the least danger of damaging eyes is apparent, such as breaking rocks with a rock hammer or heating liquids wear approved safety glasses.

d) Have a satisfactory location and humane home for animals.

e) Arrange for proper care by responsible persons (such as the principal, school peon, or parent) for burns, cut, scrapes, and scratches.

f) Send a note to parents informing them of the precautions to follow when they work at home with their children in a creative science endeavor.

Remember the 3 Ps: Planning, Preparation, Precaution and a safe creative science experience will be yours.

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ACTIVITY -5

1. *Walk around the school laboratories while they are empty and make a list of all possible sources of danger that you can find.*

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   Make a list of the possible dangers facing pupils in one lesson you observe or teach

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   Then, in each case, discuss your list with your supervisor to compare your awareness with that of an experienced teacher.

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2. *What dangers in the laboratories did you observe? Suggest simple remedies or precautions that should be taken?*

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4.6.2 Hazards and Remedies in Schools

Some examples of toxic chemicals which affect on the human.

S. No.	*Examples*	*Types of Hazard*
01	Mercury vapor	Cumulative poison to all tissues
02	Phospine	Attacks liver and kidneys and nervous system
03	Bromine, chlorine, iodine	Damage to skin, eyes, and respiratory system, liquid bromine is also a fire hazard

04	Nitrobenzene	Causes anemia and liver damage
05	Phenyl amine, (aniline)	Absorbed through the skin, attacks the nervous system
06	phenol	Caustic, absorbed through the skin, attacks the nervous system
07	Hydrogen sulphide	Paralyses olfactory organs so that it is no longer detectable by smell
08	Benzene	Liver, kidney damage, anemia
09	Tetra chloromethane	Liver damage
10	Trichloromethane	Nervous system affected
11	Ammonia	Attacks mucus membranes, e.g. in eye, nose
12	Asbestos	Fibrosis of lungs

Some of the common causes of fire are shown in below table:

Causes	*Notes*
Ignition of solvent vapors, e.g. ethoxyethane (diethyl ether), carbon disulphide, petroleum ether	Some dense vapors accumulate in layers on benches, some solvent vapors ignite well below red heat
Ignition by reactive chemicals, e.g. white phosphorus, alkali metals, and their peroxides	Appropriate storage and disposal techniques are essential, store incompatible chemicals well away from each other
Local heating due to chemical faults	Appropriate fuses are essential
Storage of hot apparatus , e.g. heating blocks, charcoal blocks	Cool thoroughly, in water, before storing in a suitable place, hot blocks may well ignite laboratory benches
Uncontrolled chemical reactions	Rehearse experiments and use only minimum quantities
Loose clothing or hair ignited by Bunsen burners	Bunsen flames are often invisible in sunlight

Electric hazards: The most obvious danger in using electrical equipment. Electrical apparatus should incorporate safety devices and be properly used. Switches should

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break the live circuit and equipment should carry a distinctive on / off light. Earthling of metal cases of all electrical equipment is essential. All equipment, especially if it is portable, should be inspected regularly.

Mechanical hazards: Any equipment with moving parts constitutes a hazard if it is misused or fails to operate properly. Gas cylinders are widely used in schools and most accidents involving cylinders arise from their misuse. Always open cylinder valves slowly and store cylinders securely in a vertical position. Always use a cylinder with a pressure regulator and do not connect a cylinder to any apparatus without first establishing and controlling the rate of gas flow.

Positive approach to safety: You must be able to oversee the activities of all the pupils in your class and be able to have rapid access to the site of any incident without delay to stools. Examine any laboratory in which you work from the safety point of view and recommended any necessary alterations. Of particular importance are the locations of firefighting equipment and of the water, gas, and electricity main controls. The fire extinguisher need be fixed on the wall of the lab.

Instruction for the students: Teacher should give the following instruction to the students.

You may not enter or work in the laboratory unless a science teacher is present (or unless you have permission to do so for a particular purpose).

You must report all accident and spillages immediately to the teacher in charge.

Chemicals must not be tested. Food and drink must not be brought into the laboratory.

Laboratory materials may not be taken outside without permission.

Never use more chemicals or materials than are recommended, and never carry out any extra experiments which may interest you without first asking the teacher in charge.

Wash your hand thoroughly at the end of lab work

Six Rules for School Safety: Back-to-school does not have to mean back-to-worrying. Though safety inside school is ultimately the responsibility of the principal and school staff, parents can take a few basic steps to ensure a safe school experience. These are recommended by the *National Association of Elementary School Principals:*

1. **Learn the school's emergency procedures.** Emergency plans and phone numbers are usually included in school handbooks and posted in classrooms. Taking a few extra minutes to familiarize yourself and your child with emergency information can give him the confidence he/she needs to act quickly in emergency situations.

2. **Know travel routes to and from the school.** Make sure you and your child know both primary and alternate routes. In an emergency, roads can be blocked and it's important to have a backup plan.

3. **Know and follow school security and safety measures.** These might include signing in when visiting the school, being escorted when walking through the building, or wearing a visitor pass. Following these procedures also sets a great example for your kids.

4. **Talk with your child about safety.** Be specific. Talk about instinct and paying attention to funny feelings of fear. Explain what to do if she doesn't feel safe (find a teacher, call 911, etc.). Make sure she knows how to contact you or a trusted neighbour who is likely to be at home.

5. **Inform school staff about health and emotional concerns.** Whether your child has a food allergy, a physical disability, or has been subject to bullying, make sure to keep your child's teachers and principal in the loop.

6. **Get involved.** Talk with the principal about what you can do to increase school safety, such as organizing parents to form a neighbourhood watch before and after school. Sometimes parent groups are highly successful in making improvements in traffic safety during drop-off and pickup times.

First Aid Kit:

1. Bandage of 2" and 4" width.
2. Cotton
3. Betadine lotion (100 ml)
4. Betadine ointment (15 gm)
5. Savlon (100 ml)
6. Paracetamol syrup (100 ml)
7. Paracetamol tablets (30)
8. Combiflam tablets (20)
9. Silverex sulphadiazine cream (15 gm) – for burns

Some common safety: The safety conscious teacher is one who is aware of potential hazards and who takes appropriate preventive measures when planning his practical work. Safety is thus a positive activity which affects all the tasks in which you and your pupils engaged. Your lesson planning should identify not only the most likely accident in any teaching situation in which you are involved, but also the maximum creditable accident that could happen. It is your responsibility to be able to deal with either of these situations should they arise.

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ACTIVITY-6

What measures will you plan for your school safety? Illustrate with various situations

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4.7 LET US SUM UP

The achievement of science and technology today are all due to the experiences. It is concerned with the learning of the minds of the pupils and as a result of this everything the pupils learn become permanent. It satisfies the instincts of curiosity, creativeness, constructiveness, self-expression, self-assertion etc. Therefore, science teaching should be on a sound psychological footing. It provides training in scientific method and inculcates scientific attitudes among the students. It develops many social desirable habits and safety measures by giving optimum giving hands on experiences to the pupil.

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4.9 UNIT-END EXERCISES

1. What is the meaning of hands on experiences in teaching science? Illustrate your answer selecting any two topics of your choice.

2. Classify the learning experiences. Discuss its importance. What criteria need be chosen for hands on experiences?

3. Discuss the types of investigations with examples.