MANGALORE UNIVERSITY

CENTRE FOR DISTANCE EDUCATION
MANGALAGANGOTHRI - 574 199
DAKSHINA KANNADA DISTRICT, KARNATAKA STATE

COURSE 7
Pedagogy of School Subject - I (d)

PHYSICAL SCIENCE
(Curriculum and Pedagogic Studies)
BLOCKS 1 & 2
(PART - 1)

B.Ed. DEGREE PROGRAMME
(OPEN AND DISTANCE LEARNING)

SECOND YEAR B.Ed.

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Contents

Overview of the Course

As we are dealing with the pedagogical aspects of Physical Science, we must gain all the knowledge that is necessary for effective teaching of this subject. A teaching-learning process consists of several stages beginning from planning, execution to the evaluation stage. The teaching-learning process will be successful only if each of these stages is meticulously addressed. This paper tries to acquaint the student teachers with the necessary knowledge related to teaching Physical Science subject. It encompasses an in-depth view of the concept, methods and strategies essential for the planning, transaction and evaluation in teaching Physical Science.

The first block introduces the nature and objectives of teaching Physical Science. This understanding lays the foundation for further understanding of all other concepts under this paper. The second block discusses the approaches and strategies for learning Physical Science. Physical Science is a skill-oriented subject and requires a hands-on approach for understanding and applying it. The different approaches and strategies that are useful in making Physical Science learning effective are introduced across this block. The third block consists of knowledge related to Curriculum and Learning Resources in Physical Science. The units under this block cover the essential aspects of selection and organization of content in a Physical Science Curriculum. The learning resources, both the traditional and modern are introduced giving prominence to ICT which is the need of the day. The last block concentrates on all the aspects of planning for teaching and assessment in Physical Science. This is an important block since it digs into the basics of a teaching process. Planning the teaching is the most important phase in the teaching process. It expands from planning the unit to planning the lesson and along the way planning the assessment. The intricacies of planning are discussed along this block.

Detailed browsing of this material will prepare a student-teacher to confidently apply the teaching-learning strategies that are needed for effective teaching of the Physical Science Subject.

Block 1 : Nature and Objectives of Teaching Physical Science

Unit 1 : Nature of Physical Science

Unit Structure

1.1.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Understand the meaning and definition of Science and physical science;
- Internalize nature of physical science;
- Identify Processes and products of physical science;
- Realize the components of Process and product of physical science; and
- Understand the areas of physical science.

1.1.2. Introduction

This modern world is a world of science and technology. The whole world is under the magic spell of science. The physical world has been enriched due to the advancement and contribution of science. Machines in the industry, equipment and medicines in the hospitals, home utility facilities, agricultural products and production enhancing materials, educational supplementary technologies, transport facilities adventures in the space are some of the examples of the contribution of science. In a way, there is no area untouched by science and technology. We get up in the morning and use toothpaste to brush and soap to wash. To cook food we use LPG and Microwave Oven. To store prepared food products and ingredients we use the refrigerator. To churn ingredients while preparing food we use a mixer and grinder. Dish wash / liquid cleaner is used to clean the dishes. Starting from the kitchen which is an essential part of every home, equipment is used in an unlimited manner. There are computers, televisions, air coolers, fans, washing machines, room cleaners, vehicles (Two-wheelers and four-wheelers) and mobiles. The extension of these scientific-technological equipments are there in our society and as well in the whole world. Scientific gadgets help us to lead life comfortably.

From the above explanation, it is evident that science has its utility value and that is the reason for its popularity. Our life is completely engulfed by the science. We cannot live without science.

Hence in this Unit 1 of Block 1, we study the nature of science in general and physical science in particular (Which is one of the branches of science).

1.1.3. Learning Points and Learning Activities

1.1.3.1.Meaning and Nature of Science

a) What is Science?

Humans are curious by nature. This curiosity has driven them since time immemorial to explore the world around them. Initially, the pace of exploration was slow. But with the availability of better tools of exploration in the last few hundred years and also as a result of the industrial revolution in the west, the pace of exploration has increased manifold. Humans' exploratory activities have resulted in the accumulation of a vast source of knowledge called natural science. In natural science, we study nature which means the entire universe. The knowledge is now organized in several disciplines for the convenience of study. This knowledge is based on inquiry, observations and logical extensions, and is testable by experiment or has a logically convincing explanation. It is this organized knowledge with inquiry, logical reasoning and experimentation as its central themes, that we call science. Science may rightly be said to be a domain of inquiry.

Before learning about the nature of physical science it is required to learn what is science? The term 'science' originated from the Latin word 'scientia' it means 'knowledge'. . . . anybody can know. – (C.W. Owen). Acquisition of knowledge improves our mental capacity

b) Definitions

Science is defined in several ways by different individuals. Let us examine a few definitions.

According to **Fitzpatrick:** "Science is a cumulative endless series of empirical observations which result in the formation of concepts & theories, with both concepts & theories being subject to modification in the light of further empirical observations. Science is both a body of knowledge & the process of acquiring it".

Conant defined science as: "An interconnected series of concepts & conceptual schemes that have developed as a result of experimentation & observation & are fruitful of further experimentation & observation". **Albert Einstein** said, "only the insane can expect radically different outcomes by doing the same thing over and over again".

According to **The Columbia Encyclopedia**: "Science is an accumulated & systematized learning in general usage restricted to natural phenomenon. The progress of science is marked not only by an accumulation of fact but by the emergence of scientific method & of the scientific attitude".

According to **Gilbert Archey**: "Science is knowledge acquired in a particular way. It becomes a human activity, an attitude & an exercise of the mind that put us wherein a state of familiarity with nature".

According to **B. F. Skinner**: "Science is, first of all, a set of attitudes. It is a disposition to deal with facts rather than with what someone has said about them".

According to **Tennyson**: "Science moves but slowly, steadily, creeping on from one point to another but the progress has been rapid".

From the above definitions, three basic principles of the nature of science can be identified

- An accumulated and systematized body of knowledge
- The scientific method of inquiry
- The scientific attitude

The first point indicates the product of science while the second and third indicate the process of science. In other words, science is both a process and a product.

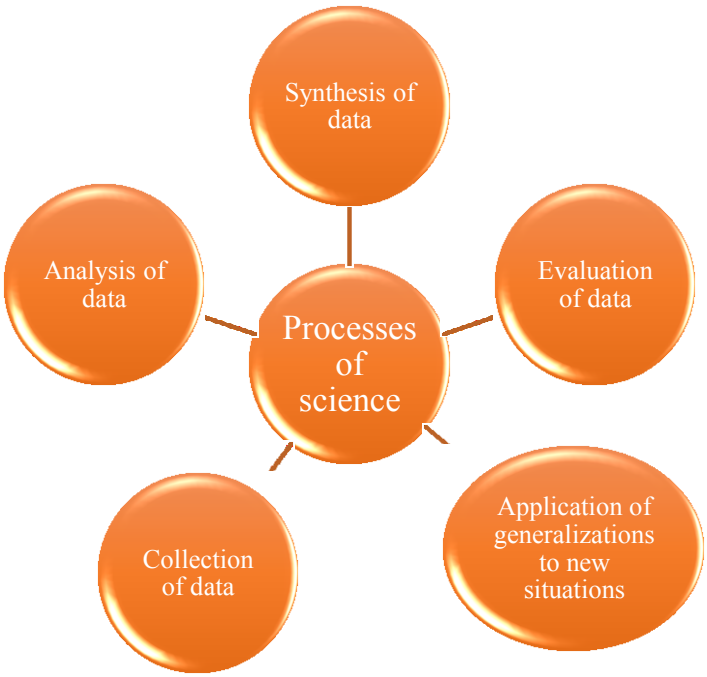
Nature of Science

Science has certain characteristics that distinguish it from other spheres of human endeavor. These characteristics define the nature of science. They are:

- Science is a particular way of looking at nature
- Science is a rapidly expanding body of knowledge
- Science is an interdisciplinary area of learning
- Science is a truly international enterprise
- Science is always tentative
- Science promotes skepticism; scientists are highly skeptical people
- Science demands perseverance from its practitioners
- Science as an approach to investigation and as a process of constructing knowledge

From the above discussion, we can understand the very nature of science as below;

a. **Science as a body of knowledge** – science has been characterized as a body of knowledge obtained by scientists. Various types of scientific knowledge exist in the form of facts, concepts, principles, laws, hypotheses & theories.
b. **Science as a process** – In science, the ways of gathering information, thinking, measuring, problem-solving are called the process of science. Basic processes of science are observation, comparison, classification, communication, measurement, estimation & prediction. The quality of knowledge acquired in science depends on the quality of process skills applied. The various processes of science can be classified into five categories as represented in the figure below:
    - ✓ Collection of data
    - ✓ Analysis of data
    - ✓ Synthesis of data
    - ✓ Evaluation of data
    - ✓ Application of generalizations to new situations



c. **Science as a product** – Whatever information or ideas we acquire through various processes of science form the product of science. The basic components of the product of science are facts, concepts, principles, theories & laws.

d. **Science as both a process and a product** – Science is both a body of knowledge & the process of acquiring it. Science is both a verb & a noun. These two aspects are interdependent & inseparable.

e. **Science is viewed as a method of inquiry** – according to Karl Pearson the scientific method involves the following six steps:
   - Identification of the problem
   - Gathering observations relevant to the problem on hand
   - Statement of hypotheses based on observations gathered
   - Testable predictions of other related observable phenomena are developed from the hypothesis
   - The hypothesis is tested through observations
   - As a result of empirical observations, the hypothesis is supported, rejected or modified.

f. **Science as an attitude towards life** – a person with a scientific attitude will have the following characteristics:
   - Open-mindedness
   - Objectivity
   - Freedom from belief in superstitions
   - Belief in a cause-effect relationship
   - Accuracy & truthfulness in reporting observations
   - Methodical way of solving a problem on hand
   - Up-to-datedness
   - Respect for other people's opinion, though he may not agree with them
   - Ability to distinguish between scientific evidence & scientific proof
   - Ability to discern between fact & fiction

A science teacher can, by his / her example, help develop these characteristics in his / her students. Our culture has a lot of variety where practices of one person may not be accepted by another person. But, we should develop an attitude of accepting other's culture and respecting it. For example food habits, we respect other food habits. This is open-mindedness.

So far we studied the meaning and nature of science. Let us now study the meaning, definitions and areas of physical science.

1.1.3.2.Process and Product Component of Science

Process Component of Science

Science can also be defined in terms of what scientists do or in other words "Science is what scientists do". There are three basic things that scientists do. They are;

- Scientists make descriptions –by using the scientific method scientists answer some of the questions like what? When? How? Where? Why? How many? How long? How frequently?..
- Scientists make explanations – it is a careful description that involves knowledge of the different factors or variables.
- Scientists make predictions. They test a condition that occurred in one situation will also occur in another situation.

Examples:

- How do day and night occur?
- Why do electric wires sag during summer?
- Why a tsunami occurs?
- Why is the sky blue?
- How is a rainbow formed?
- How is a mirror different from a lens?
- When exactly is monsoon occurring this year?
- Will the use of manures lead to a rise in the production of agricultural yields?

Hence science can be defined as the process by which we collect knowledge and increase/refine the understanding of ourselves and the universe through continuous observation, experimentation, applications and verification etc. Basic processes of science are observation, comparison, classification, communication, measurement, estimation & prediction.

Product Component of Science

Through the continuous, systematic and organized efforts of scientists some knowledge of scientific facts, scientific concepts, scientific laws, scientific theories and procedures have proved to improve our knowledge and in solving our problems. Science helps us to live happily and comfortably.

In light of the above statement about products of science, we are required to know the different product components of science.

Scientific facts:

"Scientific facts are something known to be true or accepted as true"- **oxford advanced learner dictionary**

Examples:

- Water flows from a higher level to a lower level.
- All metals are good conductors of heat.
- Day and night occur regularly.
- A metal wire expands when heated.

Scientific concepts:

"The concepts are systems of classifying the information and are generalized ideas. Concepts and process are interrelated and interdependent".

Examples:

- Sun is the centre of the solar system.
- Quantities having both magnitude and directions are called vectors.
- Refraction of light occurs when light passes from one medium to another.
- Work takes place when there is a displacement of the body in the direction of the force.

Scientific laws:

"A verified law/generalization is considered scientific law**" Encyclopedia Columbia.**

Examples:

- Newton's laws of motion
- Law of gravitation
- Law of floatation
- Kepler's law

Scientific theories:

"A scientific theory is a well-substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. Such fact-supported theories are not "guesses" but reliable accounts of the real world".

Example:

- Theory of Evolution of Earth
- Quantum Theory
- Rutherford Theory
- Special Theory of Relativity.

Scientific Principles:

"A general or basic truth on which other truths or theories can be based is the scientific principle".

Example:

- A law or fact of nature which makes possible the working of a machine or device
- The principle of magnetism.
- Archimedes Principles

Activity: 1

List some of the scientific facts, concepts, laws, theories and principles you have studied

1) _____ 3) _____5) _____7)_____
2) _____ 4) _____6)_____8)_____

Check Your Progress – 2

A) Identify facts and concepts in the examples given below:

1. Metals expand when heated
2. Work is a vector quantity.
3. Energy flows from a higher level to a lower level.
4. Acceleration is the rate of change of velocity of a body
5. Insulator does not conduct electricity
6. Refraction occurs when light passes from a rarer medium to a denser medium

1.1.3.3. Meaning and Areas of Physical Science

Physical science is a branch of natural science that studies non-living systems, in contrast to life science. Physical science is an area of science that deals with materials that are not alive and how nonliving things work. It is any of the natural sciences (as physics, chemistry, and astronomy) that deal primarily with nonliving materials.

Physical science involves several major fields of study centered on the nonliving matter or physical properties. A primary goal of physical science is to understand how nonliving matter and energy in the universe impacts human existence. It in turn has many branches, each referred to as a "physical science", together called the "physical sciences".

Physical science is

- A branch of science (a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe).
- A branch of natural science – natural science is a major branch of science that tries to explain and predict nature's phenomena, based on empirical evidence. In natural science, hypotheses must be verified scientifically to be regarded as a scientific theory. Validity, accuracy, and social mechanisms ensuring quality control, such as peer review and repeatability of findings, are amongst the criteria and methods used for this purpose. Natural science can be broken into two main branches: life science (for example biology) and physical science. Each of these branches, and all of their sub-branches, are referred to as natural sciences.
- Physical science, the systematic study of the inorganic world, as distinct from the study of the organic world, which is the province of biological science.
- Physical Science is the study of matter, energy, space, and time. It is any science that studies non-living matter.

Areas of Physical Science

It is generally considered that there are four main areas of Physical science, each of these have many subdivisions, the four main areas are:

- Physics
- Chemistry
- Astronomy and
- Earth Sciences

Let us discuss these four main areas of physical science in detail.

a) Physics: Physics is the oldest field of study, and is a natural science involving the study of matter and its motion through space-time. Physics, in its modern sense, was founded in the mid-19th century as a synthesis of several older sciences - namely, those of mechanics, optics, acoustics, electricity, magnetism, heat, and the physical properties of matter. The synthesis was based in large part on the recognition that the different forces of nature are related and are, in fact, interconvertible because they are forms of energy.

The word "Physics" originates from the **Greek** word that refers to 'nature'. It is a subject dealing with nature and natural phenomena. It is also referred to as the study of both matter and energy. It concerns both macroscopic and microscopic state of matters. Physics is an accumulated and systematic learning of the natural phenomena connected with matter and energy and the relationship between them. It also explains the material world and the natural phenomena of the universe.

The Oxford English Dictionary defines Physics as

"The branch of science concerned with the nature and properties of matter and energy. The subject matter of physics includes Mechanics, Heat, Light and other radiation, Sound, Electricity, Magnetism, and the structure of atoms."

Microsoft Encarta defines Physics as

"A major science dealing with the fundamental constituents of the universe, the forces they exert on one another, and the results produced by these forces. Sometimes in modern physics, a more sophisticated approach is taken that incorporates elements of the three areas listed above; it relates to the laws of symmetry and conservation, such as those pertaining to energy, momentum, charge, and parity."

What these definitions indicate is that physics is a branch of science that deals with the properties of matter and energy and the relationship between them. It also tries to explain the material world and the natural phenomena of the universe.

The scope of physics is very wide and vast. It deals with not only the tiniest particles of atoms, but also natural phenomena like the galaxy, the Milky Way, solar and lunar eclipses, and more. While it is true that physics is a branch of science, there are many sub-branches within the field of physics.

Physics as a discipline has the following aspects

- Physics is a process of acquiring new knowledge and refining existing knowledge
- Physics is what physicist does with a belief that knowledge is not static and needs precision.
- Exact and critical observation leads to predictions in physics
- Acquisition of knowledge is comprehensive in physics
- It is an endless process

b) Chemistry: It is another constituent of physical science. Chemistry has been defined as the study of the composition of substances and their effects upon one another. It is a science of studying chemical elements and their compounds (their composition, properties and structure) and interconversions of substances (Chemical reactions, alloys). Chemistry is the science of matter and how it changes under chemical reactions. We rely on chemistry for just

about every aspect of life, in our food, our medicines, everyday materials and microchips. All these things are developed with the specialist knowledge of a chemist.

It studies the composition, structure, properties and change of matter. In this realm, chemistry deals with such topics as the properties of individual atoms, how atoms form chemical bonds in the formation of compounds, the interactions of substances through intermolecular forces to give matter its general properties, and the interactions between substances through chemical reactions to form different substances.

Chemistry is an important subject as many professional and applied courses, directly and indirectly use the knowledge of chemistry. Chemistry is essentially the most significant aspect of modern science that has an impact on solving a variety of problems of practical and technological importance. As well as those related to the pressing problems of mankind. A large number of these problems require a proper understanding and application of chemical principles and processes.

Paracelus (1493 to 1541) said "the true use of chemistry is not to make gold, but to prepare medicines".

Chemistry has made a significant contribution in the fields of drugs, fuels, agriculture, animal farming, fibers; decoration etc. in addition to these there are many interdisciplinary subjects where the contributions of the chemist are significant.

Our life is full of chemicals naturally occurring and artificially prepared. Hence there are chemicals in our lives.

b) **Astronomy** – the study of celestial objects (such as stars, galaxies, planets, moons, asteroids, comets and nebulae), the physics, chemistry, and evolution of such objects, and phenomena that originate outside the atmosphere of Earth, including supernovae explosions, gamma-ray bursts, and cosmic microwave background radiation.

c) **Earth science** – an all-embracing term referring to the fields of science dealing with planet Earth. Earth science is the study of how the natural environment (ecosphere or Earth system) works and how it evolved to its current state. It includes the study of the atmosphere, hydrosphere, lithosphere, and biosphere.

Our life is full of scientific advancements. Major advantages of learning physical science are,

- Improvement in our way of living and thinking
- Proper awareness about our physical environment
- Training in the scientific method – to observe and think clearly, critically and carefully.
- Application scientific method in our life.
- Appreciate the contribution of scientists
- Develop qualities of scientific attitude.
- Application of physical science to our life.

Check Your Progress - 3

1. Explain the nature of physical science.
2. Define physics and chemistry.
3. List the major advantages of learning physical science.

1.1.4. Let us Summarise

- The whole world is under the magic spell of science. The physical world has been enriched due to the advancement and contribution of science.
- Science has its utility value that is the reason for its popularity. Our life is completely engulfed by the science. We cannot live without science.
- The term 'science' is originated from the Latin word 'scientia' it means 'knowledge'. . . . anybody can know.
- "Science is a cumulative endless series of empirical observations which result in the formation of concepts & theories, with both concepts & theories being subject to modification in the light of further empirical observations.
- Science is both a body of knowledge & the process of acquiring it".
- The basic principles of science are (i) An accumulated and systematized body of knowledge. (ii) The scientific method of inquiry. (iii) The scientific attitude
- Science is what scientists do.
- The different aspects of science are scientific facts, scientific concepts, scientific laws, scientific theories, scientific principles . . . . . .
- The two areas of physical science are physics and chemistry.
- Physics is an accumulated and systematic learning of natural phenomena connected with matter and energy.
- Chemistry is the study of the composition of substances and their effects upon one another.
- Our life is full of chemicals naturally occurring and artificially prepared. Hence there are chemicals in our lives.
- Science learning leads to the appreciation of the contributions of scientists.

1.1.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1
Answers to the fill-up the blanks

1. The word science is derived from the Latin word **Scientia.**
2. Science has both **Process and product.**
3. The process component of science resulted because of the scientific **method of inquiry** and scientific **Attitude**.
4. Scientists undertake 3 basic things they are **descriptions, explanations and predictions**.

Check Your Progress - 2
Answers to the identifying facts and concepts

1. Fact
2. concept,
3. fact
4. concept
5. fact
6. concept

Check Your Progress - 3

Answers to the questions

a) Science as a body of knowledge, science as a process, science as a product, science as both a process and a product, science is viewed as a method of inquiry and science as an attitude towards life.

b) Microsoft Encarta defines Physics as "A major science dealing with the fundamental constituents of the universe, the forces they exert on one another, and the results produced by these forces. Sometimes in modern physics, a more sophisticated approach is taken that incorporates elements of the three areas listed above; it relates to the laws of symmetry and conservation, such as those pertaining to energy, momentum, charge, and parity."

Chemistry has been defined as the study of the composition of substances and their effects upon one another. It is a science of studying chemical elements and their compounds (their composition, properties and structure) and interconversions of substances (Chemical reactions, alloys).

c) Major advantages of learning physical science are improvement in our way of living and thinking, proper awareness about our physical environment, training in the scientific method – to observe and think, critically and carefully, application scientific method in our life, appreciate the contribution of scientists, and develop qualities of scientific attitude and application physical science to our life.

1.1.6. Unit end Exercises

1. Answer the following in about 3 pages:

1. Define science and explain the nature of physical science
2. Explain the areas of Physical science
3. Define scientific facts, concepts and laws. Explain them with 3 examples each.
4. "Science is what scientists do". Explain
5. "Science is both process and product". Explain

2. Answer the following in about a page:

1. What is science?
2. Science is both a body of knowledge and the process of acquiring it." Write briefly
3. What are the characteristics of a person who has developed a scientific attitude?

1.1.7. References

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Block 1 : Nature and Objectives of Teaching Physical Science

Unit 2 : Scope of Physical Science

Unit Structure

1.2.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Understand the two major branches of physical science;
- Recognize the importance of physical science in our lives;
- Identify the various branches of physics;
- Understand the different branches of chemistry;
- Realize how the two branches – physics and chemistry have expressed into several; other branches of knowledge and application; and
- Recognize the significance of physical science in the welfare of mankind.

1.2.2. Introduction:

Science has to provide facilities in the changing society to develop reasoning and allow the applications of scientific research in society. Because this is the age of science its scope is very wider. The things we use daily are based on science. The progress of a nation is dependent on the progress of science. Agriculture, education, transport, health, physical facilities like construction of buildings, the supply of water, storage and preservation of food grains and transport all depend on the progress of science. From space to the events of life everything is in the hands of science.

What is the scope of science?

This consists of the basics of all other branches of science. This course is built around a core curriculum in physics, chemistry and mathematics for a listing of the specific courses required within the various concentrations of the physical sciences. It includes everything that you can see and many things that you cannot see, including the air around you, energy is what gives matter the ability to move and change.

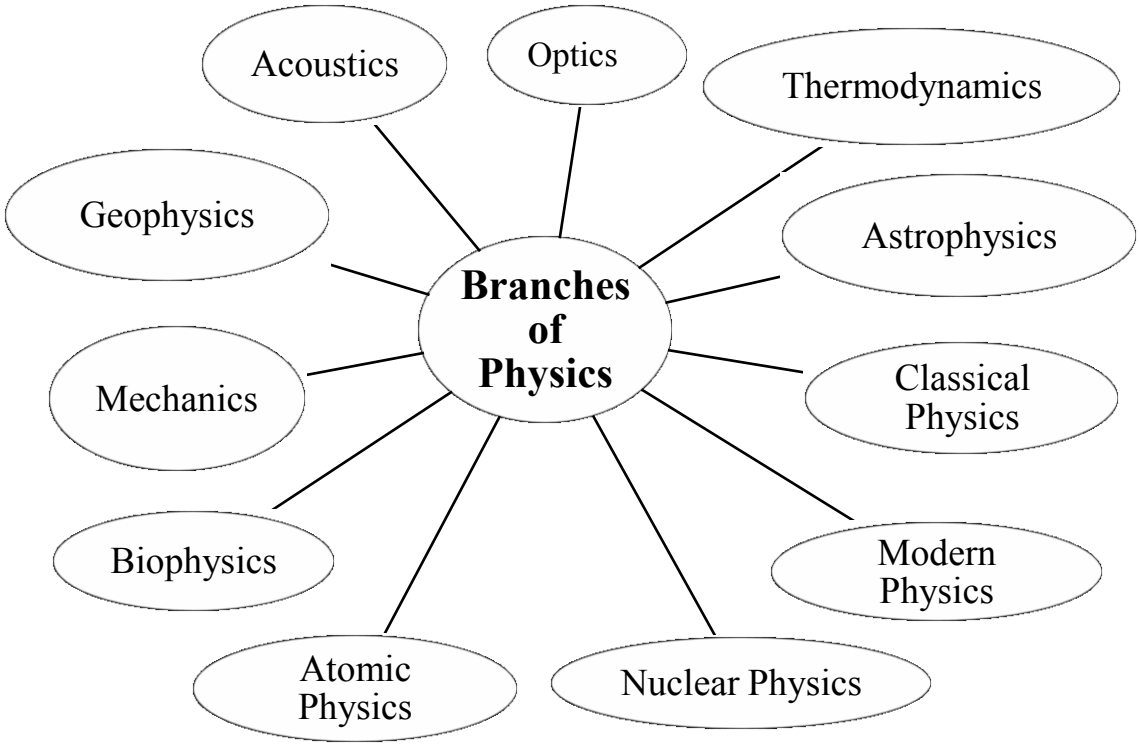
List all the scientific equipments used in the following places:

Place	Equipment's used
School	
Office	
Hospitals	

The scope of physical science can be explained in the following areas:

Relation of Physical science and other branches of science

Branches of Physics



We will discuss branches of physics and chemistry in detail.

1.2.3. Learning Points and Activities

1.2.3.1. Branches of Physics

1. Classical Physics:

This branch of physics is mainly concerned with the laws of motion and gravitation as outlined in Sir Isaac Newton and James Clark Maxwell's kinetic theory and Thermodynamics, respectively. This branch of physics deals mostly with matter and energy.

In classical physics, energy and matter are considered separate entities. Acoustics, optics, classical mechanics, and electromagnetics are traditional branches within classical physics. E.g. Newton's Laws are the outcomes of classical physics.

Physics that dates before 1900 are considered classical physics, whereas physics which date after 1900 are considered modern physics.

2. Modern Physics:

Modern physics is a branch of physics that is mainly concerned with the Theory of Relativity and Quantum Mechanics. Albert Einstein and Max Plank were the pioneers of modern physics as the first scientists to introduce the theory of relativity and quantum mechanics, respectively. In modern physics, energy and matter are not considered as separate entities. Rather, they are considered different forms of each other.

3. Nuclear Physics:

Nuclear physics is a branch of physics that deals with the constituents, structure, behaviour and interactions of atomic nuclei. This branch of physics should not be confused with atomic physics, which studies the atom as a whole, including its electrons.

"The branch of physics in which the structure, forces, and behaviour of the atomic nucleus are studied." - Microsoft Encarta encyclopedia

In the modern age, Nuclear physics has become very wide in its scope and has been applied in many fields. It is used in power generation, nuclear weapons, medicines, magnetic resonance, imaging, industrial and agricultural isotopes, and more. The history of nuclear physics as a distinct field from atomic physics begins with the discovery of radioactivity by Henri Becquerel in 1896.

4. Atomic Physics:

Atomic physics is a branch of physics that deals with the composition of the atom apart from the nucleus. It is mainly concerned with the arrangement and behaviour of electrons in the shells around the nucleus. Thus, atomic physics mostly examines electrons, ions, and neutral atoms.

One of the earliest steps towards atomic physics was recognizing that all matter is comprised of atoms. The true beginning of atomic physics is marked by the discovery of spectral lines and the attempt to explain them. This resulted in an entirely new understanding of the structure of atoms and how they behave.

5. Geophysics:

Geophysics is a branch of physics that deals with the study of the Earth. It is mainly concerned with the shape, structure and composition of the Earth, but geophysicists also study gravitational force, magnetic fields, earthquakes, magma, and more.

One of the earliest steps towards atomic physics was recognizing that all matter is comprised of atoms. The true beginning of atomic physics is marked by the discovery of spectral lines and the attempt to explain them. This resulted in an entirely new understanding of the structure of atoms and how they behave.

6. Biophysics:

Biophysics is defined as: "The interdisciplinary study of biological phenomena and problems, using the principles and techniques of physics." - Microsoft Encarta encyclopedia, Biophysics studies biological problems and the structure of molecules in living organisms using techniques derived from physics. One of the most groundbreaking achievements of biophysics is the discovery of the structure of DNA (Deoxyribonucleic Acid) by James Watson and Francis Crick.

7. Mechanical Physics:

Mechanical physics is a branch of physics that deals with the motion of material objects under the influence of forces. Often called just mechanics, mechanical physics falls under two main branches:

- Classical mechanics
- Quantum mechanics

Classical mechanics deals with the laws of motion of physical objects and the forces that cause the motion, while quantum mechanics is the branch of physics that deals with the behaviour of the smallest particles (i.e. electrons, neutrons, and protons).

8. Acoustics:

The word "acoustics" is derived from the Greek word *akouen*, meaning "to hear."Hence, we can define acoustics as a branch of physics that studies how sound is produced, transmitted, received and controlled. Acoustics also deals with the effects of sounds in various mediums (i.e. gas, liquid, and solids).

9. Optics:

Optics is a branch of physics that studies electromagnetic radiation (for example, light and infrared radiation), its interactions with matter, and instruments used to gather information due to these interactions. Optics includes the study of sight.

“Optics is a branch of physical science dealing with the propagation and behaviour of light. In a general sense, light is that part of the electromagnetic spectrum that extends from X rays to microwaves and includes the radiant energy that produces the sensation of vision.” - Microsoft Encarta encyclopedia.

Optics began with the creation of lenses by the ancient Egyptians and Mesopotamians.

10. Thermodynamics:

Thermodynamics is a branch of physics that deals with heat and temperature and their relation to energy and work. The behaviour of these quantities is governed by the four laws of thermodynamics.

The field of thermodynamics was developed from the work of Nicolas Léonard Sadi Carnot who believed that engine efficiency was the key that could help France win the Napoleonic Wars.

11. Astrophysics:

The word "astrophysics" is a combination of two Latin-derived words: *astro*, which means "star," and *phisis*, which means "nature."

Thus, astrophysics can be defined as a branch of astronomy that is concerned with the study of the universe (i.e., stars, galaxies, and planets) using the laws of physics.

12. Astronomy:

Astronomy is the science of the celestial bodies and their location, magnitude, motions and constitution. The study of the Galaxies and Milkyway helps us to understand the vastness of outer space.

13. Atmospheric Physics:

It is the study of the Physical process and phenomena of the earth's atmosphere which is divided into layers based on varying electrical characteristics and varying compositions.

14. Physical chemistry:

Physical chemistry is the use of physics to study chemical combinations, chemical problems and to provide a greater understanding of chemistry. Chemical bonds and chemical reactions.

15. Cryogenics:

Cryogenics is the study of matter at temperatures much colder than those that occur naturally on earth. Physicists are concerned with phenomena such as superfluidity and superconductivity and Bose-Einstein condensation.

16. Crystallography:

Crystallography is the subdivision of chemical physics that deals with the study of crystals that compare solids and are made up to rigid three-dimensional latticework of molecules that give rise to special properties such as shape, hardness, electrical conductivity and photo-conductivity.

17. Electromagnetism:

Electromagnetism is the branch of science that deals with the physical relations between electricity and magnetism. Lightening is electromagnetic radiation.

18. Energy:

Energy occurs in many forms and physicists seek to find the relationship between various forms of energy. Advances in Physics have had many applications in the area of energy efficiency, including the development of energy-efficient lighting, heating and cooling systems and electrical power plants.

19. Engineering:

Physics is closely related to engineering in that engineering uses physical propels in solving everyday problems and developing the application for the improvement of the quality of human life.

20. Environmental Physics:

Environmental Physicists use the principles and techniques of physics to study the earth's environment. Environmental Physicists have made contributions to understanding global climate change and the ozone hole.

21. Fluid mechanics:

Fluid mechanics and Fluid dynamics is the study of matter in the liquid state.

22. Geology:

Geologists depend on knowledge gained in physics as well as other sciences to understand the materials they are studying. Geophysics is the application of the investigation of physical phenomena in the study of the earth and its internal composition. Geology is the study of the origin of the earth, its history, its shape, the materials that constitute it and the process that are or have affected it.

23. History of Physics:

History of Physics is a branch of historical research that is focussed on the individual, institutions and processes involved in physical research. Efforts are made at archiving oral and visual history, important papers and books and interpreting these artifacts.

24. Material science:

Material science is an applied science concerned with the relationship between the structure and the proportion of materials. Materials physics has had many practical applications for the benefit of mankind and the economy; research in the area led to the development of Teflon which is found in everything.

25. Medical Physics:

Medical Physics is the application of physical research of the medical arts for the design of equipment and techniques used to safely study the human body also diagnose and treat diseases.

26. Metallurgy:

Metallurgy is the science and technology of metals ... their characteristics and behaviour.

27. Molecular physics:

Molecular physics is concerned with the interaction of the structure of atoms with the bonds between the atoms.

28. Nuclear Physics:

Nuclear Physics is the study of the structure of the atoms Nucleus and the relationship of the properties of the Nucleus to the fundamental constituents and laws of nature. The application of nucleus physics in the generation of electrical power and the treatment of cancer are just two of many that have had a major impact on mankind. It encompasses the study of the splitting of nuclei into smaller parts and the merger of nuclei into larger nuclei called fission and fusion respectively.

29. Oceanography:

Oceanography deals with all aspects of oceans including the delimitation of their extent and depth, the physics and chemistry of their water, marine biology and the exploitation of their resources. Physical oceanographers provide explanations of the physical state of oceans, particularly the distribution of water masses, the conditions that create them, and the great currents that disperse and mix them.

30. Optical physics:

Optical physics deals with the nature and properties of light and seeks to explain the optical phenomena that cannot be explained in terms of rays. Optical physicists study and use the laser in most of their studies.

31. Particle physics:

Particle physics also referred to as high energy physics is the study of most fundamental particles of which matter is made. Elementary particles are created by high energy particle accelerators and are also constituents of cosmic rays. Physicists working in this area are currently trying to discover a single unifying concept that relates to all fundamental forces and elementary particles.

32. Plasma physics:

It deals with the study of the physics of plasma which has been called the fourth state of matter Plasma possess properties not found in ordinary solids, liquids and gases. Plasma physicists have been attempting to imitate nuclear fusion by the production and manipulation of plasma in the laboratory.

33. Rheology:

Rheology applies physics to the study of deformation and flow of matter. An example of Rheology is the application of the principles behind the observation in the differences in the flow of ketchup from the bottle before and after shaking the bottle.

34. Solid state physics:

It is the branch of physics that deals with the internal structure and preparation of solids in which physicists determine how the behaviour of an atom or molecule within solids gives rise to observed properties.

35. Space physics:

Space physics is the study of the physical properties and phenomena of the region beyond the earth's atmosphere. Exploration of space is conducted to extend knowledge about the Earth the Solar system and beyond the Universe.

36. Thermal physics:

Thermal physics deals with the mechanical action or relationship between heat, work, temperature and energy.

37. Vacuum physics:

Vacuum physics is the study of matter in an environment at low pressures with little or no surrounding gas.

Activity 1:

List all the artificial satellites launched by ISRO and understand the advancement made in the field of the Indian space programme.

Check Your Progress - 1

1. What is the importance of optical physics?
2. What is Rheology?
3. What is plasma physics?

1.2.3.2. Branches of Chemistry

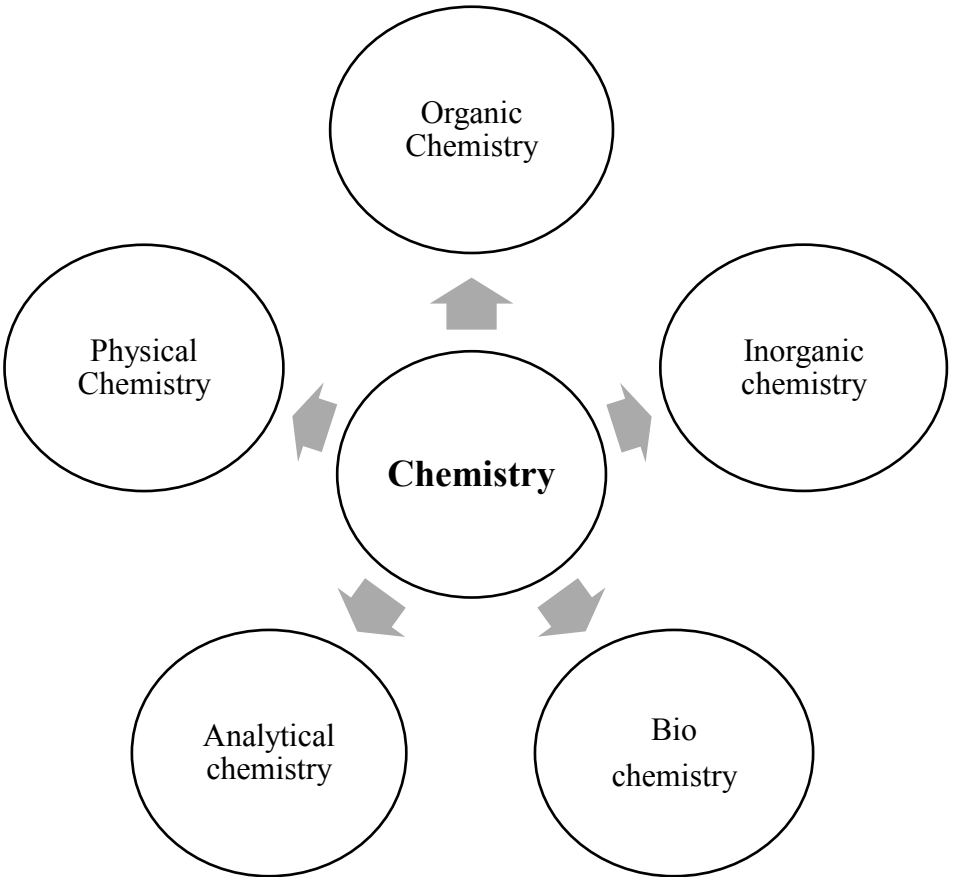
Activity 2: List the different chemicals we use in our daily life.

Sl. No	Name of the chemical	Purpose for using them

There are also branches of physics like Geophysics, spectroscopy, electronics, biophysics Astrophysics etc.

As physics, chemistry is also a branch of physical science. Chemistry has been defined as the study of the composition of substances and their effects upon one another. Let us discuss the different branches of chemistry.

The five major branches of chemistry are organic, inorganic, analytical, physical, and biochemistry. These are divided into many sub-branches.



1. Inorganic Chemistry:

It is a science of chemical elements and their compounds. Inorganic chemistry is based on the periodic law. The major tasks of inorganic chemistry are the determination of the structure of atoms of elements and a thorough investigation of elements' properties depending on their atomic structure, the study of the composition and properties of substances and the determination of their molecular structures. The development of methods for the synthesis of new materials with intended properties.

2. Organic Chemistry:

The chemistry of carbon compounds; the chemistry of carbon compounds excluding the metal carbonates and the oxides and sulphides of carbon. Originally, the chemistry of substances produced by living organisms, as distinct from the inorganic chemistry of substances of mineral origin.

It developed into a separate discipline in the 19^{th} century. At present various branches of organic chemistry have acquired the status of independent research fields. Example organ clement chemistry, the chemistry of naturally occurring substances, polymers, antibiotics, vitamins, hormones, dyes, stereo chemistry etc.

3. Physical Chemistry:

It is the most important branch of chemical science using achievements and methods of physics for the study, explanation and discovery of the patterns of chemical phenomena. Physical chemistry includes the theory of the structure of chemical compounds, chemical thermodynamics and chemical kinetics, electrochemistry and chemistry of collides, the theory of catalysis, solutions, photochemistry and radiation chemistry.

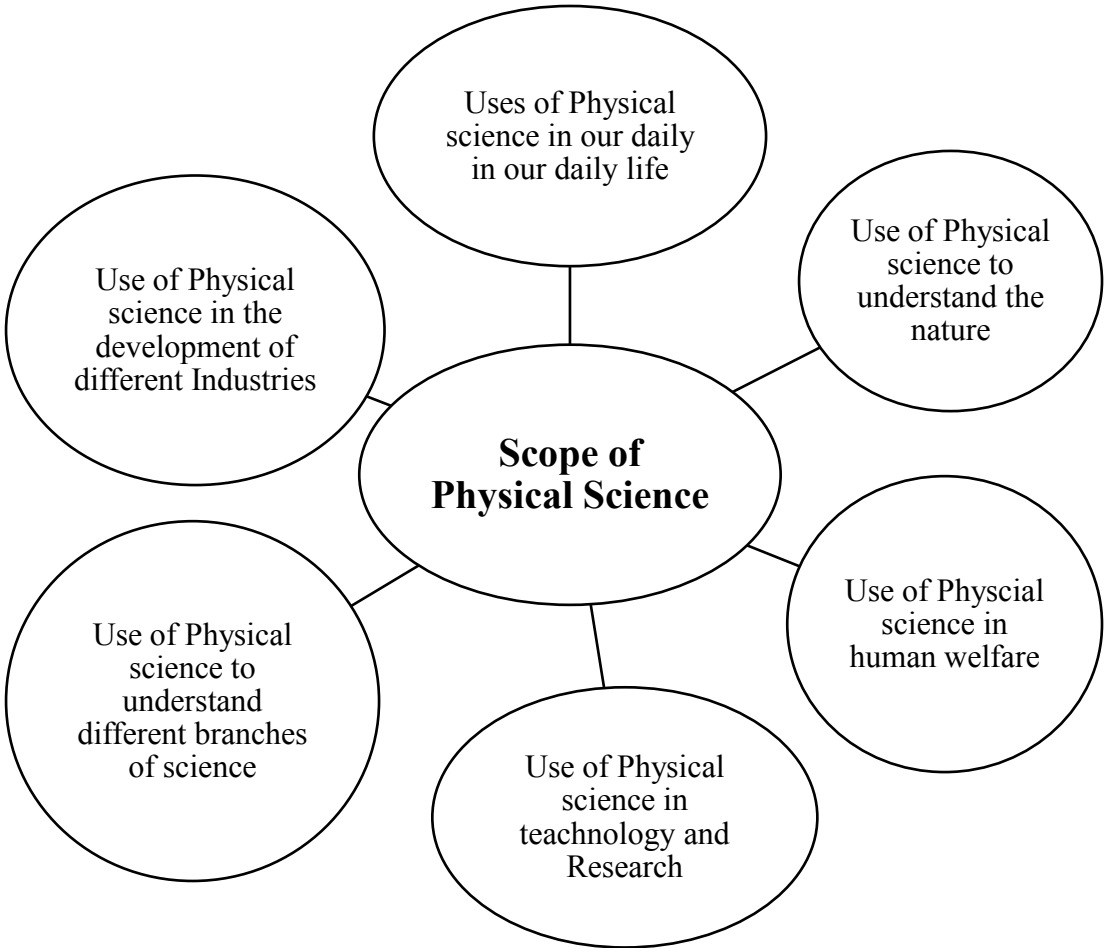
4. Analytical Chemistry:

A science treating of methods of determination of the chemical composition of substances depending on the substance to be studied. Analytical chemistry is conveniently divided into the inorganic and organic analysis.

5. Bio-Chemistry:

Biological chemistry is the science that death with the chemical composition of living organisms and chemical transformations of substances. Biochemistry is subdivided into the biochemistry of man. The biochemistry of plants and the biochemistry of micro-organisms.

Some more branches of chemistry are Biogeochemistry, Integrated science, Modular science and Marine science.



Like this, we can find a wide scope of physical science in its manifolds for the benefit of man and society. We need to appreciate and use science for the benefit of all.

Activity 2:
List the different areas of physical science and their contribution to human welfare

Area	Contribution
1	
2	
3	
4	
5	
6	
7	
8	

Check Your Progress - 2

1. What are the different branches of chemistry?
2. Differentiate Inorganic and organic chemistry?
3. Write one advantage of Analytical chemistry.

So, far we studied the scope of physical science concerning different branches of physical science. The scope of it can be revealed through the following representation as below:

1.2.4. Let us Summarise

- Physical science is useful in leading our lives comfortably through material advancement.
- Physical science has helped us to understand our nature and harness it for the benefit of mankind.
- Physical science helped us apply its knowledge in different industries.
- Physical science has played a major role in improving human wellbeing.
- Physical science is immensely used in application technology and research.
- Physical science has two important branches i.e. Physics and chemistry. They are again extended as separate branches of Physical science. This has lead to the advancement of scientific knowledge and its application.
- The different branches of physics are optics, acoustics, thermodynamics, astrophysics, classical physics, modern physics, nucleus physics, Atomic physics, Biophysics, Mechanics Geophysics, Classical physics, Modern physics, Nuclear physics, Atomic physics, Geophysics, Biophysics, Mechanics, Acoustics, Optics, Thermodynamics and Astrophysics
- The main branches of chemistry are Organic chemistry, Inorganic chemistry, Analytical chemistry, Physical chemistry, Biochemistry.
- The scope of physical science is wide and has manifold benefits for man and society.

1.2.5. Answer to 'Check Your Progress – 1 and 2'

Check Your Progress - 1

1. It deals with nature and the properties of light. It seeks to explain the optical phenomenon which cannot be explained by rays.
2. Rheology applies physics to the study of deformation and flow of matter.
3. It deals with the study of physics of plasma; the fourth state of matter plasma possesses properties not found in ordinary solids, liquids and gases.

Check Your Progress - 2

1. Inorganic chemistry, organic chemistry, Analytical chemistry. Biochemistry, Biogeochemistry, Integrated science, modular science and marine science.
2. Inorganic chemistry is the science of chemical elements and their compounds. Organic chemistry is the chemistry of carbon compounds excluding the metal carbonates oxides and sulphides of carbon.
3. A science treating of methods of determination of chemical composition substances.

1.2.6. Unit end Exercises

I. Answer the following in about 3 pages:

1. Explain the role of physical science in our lives.
2. Discuss the application of physical science in industries.
3. Bring out in detail the different branches of physics.
4. How the different branches of chemistry have benefitted us?
5. Physical science has benefited human welfare. Discuss.

II. Answer the following in about a page:

1. Explain any 3 branches of physics
2. Explain the branches of chemistry
3. Write briefly about the uses of physical science to understand nature.

1.2.7. References

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Block 1 : Nature and Objectives of Teaching Physical Science

Unit 3 : Significance of Inquiry, Observation and Experiments in Physical Science Interdisciplinary Linkages and its Societal Concerns

Unit Structure

1.3.1. Learning Objectives

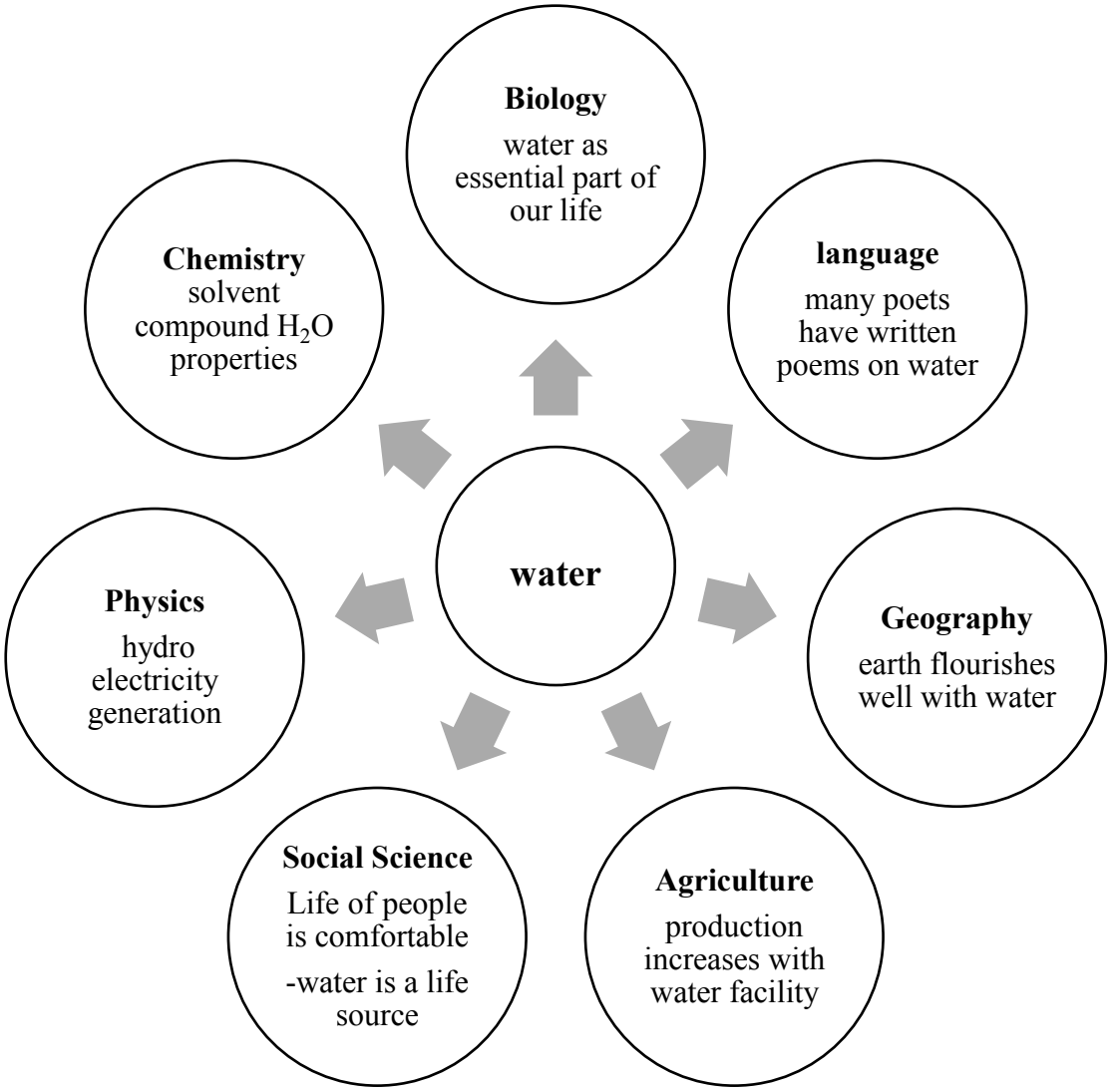
After completing this Unit, the student teachers will be able to

- Understand the significance of inquiry, observation and experiments in physical science;
- Recognize the importance of interdisciplinary linkages of physical science;
- Identify interdisciplinary linkages among science subjects;
- Find the way of interdisciplinary linkages among school subjects and physical science;
- Recognize the way of enhancing the learning of students as well as teaching effectiveness through meaningful linkages of different subjects;
- Appreciate the usefulness and concerns of physical science with the society; and
- Contribute to the development of physical science and society as a citizen of society.

1.3.2. Introduction

Activity

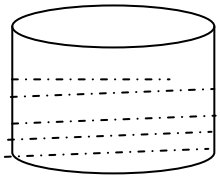
Let us consider, for instance, a lesson has to be taught on the topic "water". Let us see how this topic can be linked to different subjects.



You can observe from the above explanation that the water concept can be linked to so many subjects.

You can also plan a topic of any subject and link it to other school subjects.

All of us experience through our senses of touch or sight and use other senses also. But sometimes they may not be reliable. Consider three pans of water as shown below.



Cold

Warm

Hot

If you put your finger, first in the pan containing cold water and then in a pan containing warm water, your sense of touch will tell you that it is hot. But if you put your finger first in hot water and then in warm water, your sense of touch now tells you that the same water is cold. This shows that what you have experienced is not the truth. To justify this you require to measure the degree of hotness of water in each pan. This measurement conveys accurate information. There is quantification based on it, inference reexamines our observation to make it objective.

Students in this unit will study the importance of inquiry, observation and experiments in physical science. Science and physical science are linked to various other school subjects as well as other science subjects. Let us now study the interdisciplinary linkages, Science and physical science and its societal concern

1.3.3. Learning Points and Learning Activities

1.3.3.1. Significance of Inquiry, Observation and Experiments in Physical Science

The human being is curious by nature. Why and how does it rain? Why does it rain heavily on some days and not on other days? Why drought occurs? Why there is variation in the occurrence of seasons? etc are some questions occurring in the human mind many times. These questions are due to curiosity in man. This is the centre of human inquiry.

Inquiry learning refers to find answers to questions in mind along with various resources from surroundings to collect information knowledge, data and idea. These resources may be in the form of daily experiences, newspapers, books, pictures, texts, stories, local animals and plants and things around, diagrams, animations, video, movie clips, websites what's app messages etc. We can say that inquiry-based learning promotes knowledge and its generation, (the first level of the cognitive domain in Bloom's taxonomy of educational objectives). Scientific inquiry is a way to investigate things and propose explanations for observations. Scientific inquiry requires following the usual set of procedures of the Scientific method to define the problem, setting hypothesis, design an experiment observing and recording data, analyze and interpret it and firmly draw conclusions. This is not the only procedure. There may be variations in the procedure followed to solve a problem. A scientific inquiry may seek changes in procedures to solve problems with needed variations.

Some of the following points reveal the significance of Inquiry in learning Physical Science:

- It improves the understanding of core concepts and reinforces curriculum content.
- It 'warms up' the brain for learning. Helps students absorb information throughout the day.
- It promotes a deeper understanding of the content.
- It helps students to take ownership of their learning
- It promotes deep learning
- It builds imitative and self-direction for self-guided learning
- It works in any classroom
- It offers differentiated instructions
- It uses a heuristic way of learning
- It allows explanations based on evidence
- It considers new explanations
- It helps to add further explanations
- It helps to define questions
- It helps to exhibit curiosity
- It helps to carry out simple investigations
- It explains based on evidence

To summarize, inquiry promotes the development of following in the students.

- Inquisitiveness
- Innovativeness
- Informativeness
- Individualization

Significance of Observation in Physical Science

"Sound observation can be made if one has observation competence" - Stephen Norvis (1984).

"Observation is a process of determining the likeness and differences in single objects that vary in their physical characteristics as detectable by any of the senses". – Gagne (1965).
The **four elements of observation** are

- The observer
- The object
- The process of observation
- The product of observation

For example, the teacher wants to show the attraction and repulsion property of magnets, the observer (student), and the object are (2magnets). When opposite poles (N-S) of two magnets are brought there is an attraction between magnets and when the same poles of magnets (S-S) are brought together there is repulsion between them. (Process of observation).

By observing this phenomenon, the students in the class recognize and arrive at a conclusion that opposite poles of magnets attract and the same poles repel. (Product of observation).

Observation involves

1. Objects directly observed (e.g. rubber ball and cork ball; cyclist and motorist)
2. Changes that take place before, during and after the process of change (e.g. the burning of a paper).
3. Objects that exhibit effect rather than their appearance (e.g. rays of light focused through a convex lens).
4. Objects are observed in terms of their effects or functions rather than their appearance.
    i. Force can be seen only because of its effect
    ii. Magnets exhibit properties only in the presence of iron
5. Observation of reports available verbal, pictorial, symbolic, graphical, extracts etc. (e.g. Historical reports of scientific development).

Impact of the momentum of a heavy object on a lighter one

Activity:

1. Observe the candle and record your observations
2. Burn the candle and observe once again record your observation
3. Put off the candle, observe and record your observations.

Before	While Burning	After Burning

Significance of Experiments in Physical Science

"If you want to know the essence of the scientific method, don't listen to what a scientist may tell you. Watch what he does when engaged in scientific work, not when he is taking a holiday or is on a picnic or discoursing on something beyond his competence". – Einstein

Dear students, to understand science, we need to observe what scientists do regarding science.

Some students in your class may say that they have learnt about a concept/theory well after observing/doing the experiments.

Example 1: while teaching static electricity, the fundamental law "like charges repel and unlike charges attract, whatever explanation given by teacher may fail to bring a clear understanding of the law. Hence the teacher can do the following experiment.

- Rub a rubber rod with fur and a glass rod with silk.
- Both rubber rod as well as glass rod have been electrically charged.
- On bringing these two rods close together, it is observed that they attract each other.
- On bringing two charged rubber rods or two charged glass rods close together, the effect is seen as repulsion.
- Glass rod always acquires a positive charge because it tends to lose the loosely bonded electrons. Hence, it is said to be charged positive. Rubber rod always acquires a negative charge because it tends to gain electrons from other substance.
- Hence, it is said to be negatively charged.

Conclusion: Like charges repel unlike charges attract.

Thus, students clearly understand this law of static electricity. This proves the value of experiments.

Example 2: Archimedes principle says that whenever an object is partially or completely immersed in any liquid, the loss of weight of the object is equal to the weight of the liquid dispelled from it.

This law can be verified by taking an overflow jar; an object tied to a thread a beaker and a spring balance. The weight of the object in the air is measured by using a spring balance and it is recorded. Then, this object is immense in water (partly / completely) and weight is measured. Students are asked to observe what happens? Weight is measured and recorded. Students are asked to observe the two readings of weights. Weight of object in air = w_1 grams. Weight of the object in water = w_2 grams. Weight of the water overflowed = $w_3$gms ; w_1 gms - $w_2$gms = $w_3$gms. Thus, this verifies the Archimedes principle.

From the above two examples, we can have a glimpse of what is the significance of experiments in science teaching and learning.

Experiments may be conducted indoor/outdoor. It has the following significance:

- It clarifies doubts and enhances the learning of students.
- It quenches the curiosity of knowing and understanding.
- It encourages learning by doing.
- It is based on activity and hence students are kept active.
- It overcomes the boredom of class.
- It improves student's span of memory.
- It clarifies the puzzling aspects of learning.
- It develops ownership of learning in students.
- It develops the alternativeness of students.
- It helps students to analyze data, examples or models.
- It helps students to respond to what they observe.
- It strengthens the group work of students.
- It leads to the manipulation of some of the things in the experiment and observes the changes (outcomes).
- It helps students to compare theory and practice and criticize if the variation is there.

Thus, conducting experiments in science classes, in laboratories or outside will contribute and strengthen the learning of science. Thus, learning science through experimentation is an important process of Science learning. This realizes the way that is followed by scientists to discover/invent.

Check Your Progress - 1

1. Which is the most basic science process skill? What is its purpose and how it helps science learning?
2. What is scientific inquiry? Why is it important in the learning of science?
3. Write any five advantages of science experiments.

1.3.3.2. Interdisciplinary Linkages in Physical Science

A linkage, as the word signifies, is the reciprocal relationship between various subjects of the curriculum. The child is interested to learn the things which are related to his experiences. They cannot learn various subjects in isolation. While teaching, say biology, we can forget that physical science has an equal contribution to the field of biological studies. So the interdisciplinary linkages correlation of different subjects is very essential for linking makes study easier, more interesting and natural.

The principles of interdisciplinary linkages demand that various subjects contribute to the child's education in the manner and to the extent that they help him to understand his environment better and carry out activities that have meaning for him.

Interdisciplinary linkages of science subjects with one another:

All the branches of science are interdependent upon one other and there are many facts and principles which are common to various science subjects. It is often heard by the teacher saying that he can teach his subject, say biology, without knowing even a b c of physics and chemistry. It is this state of ignorance of the teachers and the absence of willingness to learn from other branches of science that have resulted in the loss of interest of the students in a particular subject. This, however, does not mean that the teacher of one branch of science ought to know everything of other branches of science but it is very much essential that he should have sufficient knowledge of other sciences so as that it brings about the integration of subjects. He should also know where to depart from his subject and how much should he venture into areas which are not directly related to the subject of study. To Elucidate the point, we take the following statement.

It is said that "there is no equal to knowledge and Knowledge is power". It has to be acquired as a 'whole' but not in bits. It becomes the duty of the teachers to integrate the different subjects taught by them. Then only learning of the subjects becomes effective, meaningful and long-lasting. Teacher/teachers teaching different school subjects must find different linkages between the school subjects and blend them in such a way that there is a linkage between subjects taught in the school.

You as the teacher may think about the relationship between subject/topics/concepts of different subjects. Finding such a thing is called linkages between the subjects. It is also named interdisciplinary linkages. Here below we find the linkages of physical science with other subjects like science subjects, mathematics, history, geography, languages, crafts, fine arts, the social and physical environment and music etc.

Importance of Linkages in Science Teaching

During teaching some fact, phenomenon or principle of science immediate reference should be made to its application and to other factors to which it is related. The application of science to our life and in agriculture, engineering medicine, communication etc., is widespread. Science should not be taught without reference to its relations with these fields.

Many natural phenomena that we see in our everyday life can be explained with the help of simple scientific principles. In every topic, there can be innumerable local examples, whether it is an urban area or rural. Such linkages make the teaching of science interesting and realistic. The students feel that science matters to everybody and they begin to take interest in the world around them.

Water supply, Fish farm, Photography, Water purification, Disinfectants Insecticides Manures etc. provide examples of everyday use of science.

a) Interdisciplinary Linkages of Physical Science with other School Subjects

Science can be linked with almost all the school subjects. A mountain provides to the physics teacher an example to discuss the center of mass or difference of atmospheric pressure at the top and the bottom of the gravitational pull towards it. A history teacher will probably describe its strategic position in the defense of a country or its historical background. The teacher of literature would perhaps like to describe the physical beauty of the mountain.

Motion and rhythm mechanics and the design of instruments are other examples. Science students are required to make intricate drawings, and charts, diagrams, graphs etc. in physical sciences. They often have to make models and draw diagrams of the apparatus and equipment used in the laboratory. In zoology, they often have to draw living and nonliving animals and the enlarged diagrams of what they see through the microscope. Here they need the imagination of an artist. Therefore, science or scientist is dependent on the arts or the artist. There are also examples where art is dependent on science. Work in arts depends on the production of good brushes, pencils, etc. Some persons can contribute both to science as well as to arts. An example of such a personality is Leonardo Da Vinci.

Students you have heard the story of Archimedes and the king of Syracuse. Archimedes found a solution to a problem when the king asked him to examine the purity of his crown. Archimedes got royal patronage in his search for scientific truth. Similarly, Aristotle, Newton and many scientists had to work against the prevalent social trends to discover scientific principles. The events of history, when connected with contemporary scientific discoveries make the learning of science more interesting.

b) Interdisciplinary Linkages of Physical Science with History and Geography.

The history of science is a subject equally interesting for both scientists and history lovers. The books like “The History of Man”, “The story of the Earth”, “The story of the Atom”, “The story of the Moon”, bear testimony to this. The history of scientific inventions and discoveries provides useful background for the teaching of history. The correlation between science and history is best sought in topics like the story of earth, the story of man, the story of the moon, etc. Several important discoveries and inventions were made in the reign of certain kings. Reference should also be made of such scientific achievements while teaching about those or periods and vice-versa.

Many facts and principles of science and geography are common topics. Examples may be cited of topics on air, water, barometer, thermometer, rain gauge, the eclipse of the sun and the moon, motion of the planets, metrological topics etc. Geography makes use of the science equipment for its purpose and interprets the results; chemistry of rocks may be a topic for discussion either in geography or in chemistry.

c) Interdisciplinary Linkages within Science Subjects

For example, the gas laws, electrolysis, air, water, cells, atoms, and molecules, crystals etc., are topics that may belong to both the fields of physics and hygiene or physiology. The topic light may be discussed in physics, physiology and hygiene. The lessons on the eye or the ear may belong to the field of physics or physiology. The barometer or the rain gauge may be topics of physics or geography. Oil is a topic common to the field of

chemistry as well as geology. Various branches of general science may be correlated through topics of general science. For example, healthy living, cleaning, nutrition and food preparation, home management, use of the first aids, etc., involve applications of various branches of general science. The working of our bones and muscles can be compared with the working of various types of levers. Thus physiology and physics mechanics can be linked, Rest and sleep, digestive system, circulation of blood, etc., are common topics of physiology, hygiene and biology. Physical conditions affect the mental condition; thus physiology may be linked. The use of electricity in the home combines electricity physics and hygiene. Humidity is a topic that may be taught either in physics or in geography. Similarly, mariners compass is a topic that may come up for discussion either in physics or in geography. Every branch of science is developing fast and each branch is becoming more and more dependent on other branches. The various special branches of science are being combined to form new areas of science such as biochemistry, biophysics, geophysics, physical chemistry, physical-geography, economic botany, electro-chemistry, mathematical physics etc.

There is a branch of physics known as acoustics. A tabla or mridangam is treated as a loaded membrane in acoustics, a sitar or guitar as a plucked string, a violin as a bowed string, a piano as a struck string, a symbol as a vibrating metal disc etc. Music can now be made more appealing through the application of science. Electronics have brought about great innovations in the world of music.

A bio-physics teacher while teaching the sense organs says an eye should make a parallelism with a camera, which the students have learnt in physics. The teacher is teaching the same topic in the period of human physiology say the defects in the eye

A biology teacher while teaching the digestive system should have adequate knowledge of chemistry without the help of which he cannot justify the treatment of the topic. Almost all the topics in all the branches of sciences are somehow related to one another and the teacher should try to bring about an integration between them. Hygiene and domestic science are such subjects that have a natural combination of all the branches of science and the teacher cannot escape and should not escape the use and importance of subjects other than his own in teaching such subjects.

d) Science and Language:

The students of science often have to write essays on scientific topics and notes on their laboratory experiments. They should be encouraged to write in distinct, lucid language.

Science teaching and learning is not focused on the expression abilities of students. The science students must be able to express their thought in clear, concise, correct and attractive language. This is only possible if the science teacher and language teacher take up a joint responsibility for the cultivation of a good style in answering essay type questions and in written accounts.

Science contributes significantly to the teaching of English in our schools by actively promoting the skills of reading, writing, speaking and listening. Some of the texts that the children study in the Literacy Hour are scientific. The children develop oral skills in science lessons through discussions (for example of the environment) and through recounting their observations of scientific experiments. They develop their writing skills through writing reports and projects and by recording information.

e) Interdisciplinary Linkages between Science and Mathematics

Science contributes to the teaching of mathematics in many ways. The children use weights and measures and learn to use and apply number. Through working on investigations, they learn to estimate and predict. They develop the skills of accurate observation and recording of events. They use numbers in many of their answers and conclusions.

f) Interdisciplinary Linkages between Science and Information and Communication Technology (ICT)

Children use ICT in science lessons where appropriate. They use it to support their work in science by learning how to find, select, and analyse information on the Internet and other e-learning resources. Children use ICT to record, present and interpret data and to review, modify and evaluate their work and improve an assigned presentation. They also use e-mail to communicate their mathematical findings with other children in other schools and countries. Science and ICT are interlinked and help in enhancing teacher's teaching and student learning.

g) Interdisciplinary Linkages between Science and Personal, Social and Health Education (PSHE) and Citizenship

Science makes a significant contribution to the teaching of personal, social and health education. This is mainly in two areas. Firstly, the subject matter lends itself to raising matters of citizenship and social welfare. For example, children study the way people recycle material and how environments are changed for better or worse. Secondly, children benefit from the nature of the subject in that it gives them opportunities to take part in debates and discussions. They organize campaigns on matters of concern to them, such as helping the poor or homeless. Science promotes the concept of positive citizenship.

h) Interdisciplinary Linkages between Science and Spiritual, Moral, Social and Cultural Development

Science teaching offers children many opportunities to examine some of the fundamental questions in life, for example, the evolution of living things and how the world was created. Through many of the amazing processes that affect living things, children develop a sense of awe and wonder regarding the nature of our world.

Science raises many social and moral questions. Through the teaching of science, children have the opportunity to discuss, for example, the effects of smoking and the moral questions involved in this issue. We give them the chance to reflect on the way people care for the planet and how science can contribute to the way we manage the earth’s resources. Science teaches children about the reasons why people are different and, developing the children’s knowledge and understanding of physical and environmental factors, promotes respect for other people.

Similarly, the historical events and the biographies of scientists provide excellent reading material.

Check Your Progress - 2

1. What are interdisciplinary linkages?
2. Give one example for interdisciplinary linkage between
    a. Science subjects
    b. Science and history

c. Science and geography
d. Science and languages
e. Science and mathematics

1.3.3.3. Physical Science and its societal concerns

By trying to answer the above questions are you not realizing the contributions of science and scientists to us the members of society? You will think of the contributions of science. As a teacher of science, you have realized some of the advancements of science and its role in our lives. You have to help your students to know the link between science and society. What science has gifted us to improve and modernize our lives are to be discussed in the classes. This becomes the duty of science teachers. Let us learn about the contribution of science to improve our society.

Read the following questions, think of the response

- Can you imagine your life without electricity? What would happen if there was no electricity?
- What are the improvements in transportation due to scientific inventions?
- What are the contributions of scientists in the field of communications?
- What are the miracles produced by science in the field of medicine?
- What is the leap that the Indian space programme has now?

Dear students from the above descriptions you observe how science has influenced society. It has contributed to the welfare of society. They may be listed one by one as below:

Physical Science and Society

One of the important aims of education is to help students to become responsible democratic citizens of the country. The responsibility of science teachers is not only to teach facts, principles and processes of science but also to facilitate students to discharge their social responsibilities and preserve democracy as well. They should appreciate how science and technology have developed and are affected by many diverse individuals, cultures and societies.

Science education aims to make students develop a scientific attitude so that in later life they can help society make rational choices when confronted with various possibilities and challenges. For example, a society wishes to augment its energy resources; there are many possible ways in which energy can be generated. Society wishes to opt for a method that is the least harmful ecologically. If the level of science literacy is high in society then its citizens are in a better position to make the correct choice.

Science has influenced and benefited us so immensely that it has become indispensable. At the same time, society has also helped science to grow. Science enhances the quality of our life and it is visible in all walks of life. The need for society has always played a very important role in the development of science. Science research many a time makes a dramatic shift according to the need of society.

There are many science and technology-oriented issues and problems which can be tackled by the scientific community in collaboration with various organizations, communities, societies and government. Examples of such problems are community health, population growth, safety from natural and human-induced disasters and infectious diseases, depleting natural resources, endangered wildlife concerns, etc. Each member of society needs

to consider these problems as his/her own. Students should not only be aware of the relevance of scientific discoveries and development in their everyday life but use it for the benefit of society. Students should be made to realize that social development affects progress in science and vice versa. Students should enrich their educational experiences by understanding the impact of issues such as energy crises, genetic engineering, nuclear testing, Genetically Modified(GM) crops, and global warming on modern society for its well-being.

We see that science and society influence each other. Educational aims are framed following our socio-economic and socio-cultural needs. Some of the aims of teaching-learning science are:

- to develop the scientific temper, attitude and honesty;
- to develop open-mindedness, national integration, concern for the environment and democratic values;
- to respect others' view and opinion, to develop gender equity;
- to produce such professionals liked actors, engineers, scientists, teachers; and
- to promote research in the field of science and technology.

Now extensive research is being conducted in the field of information technology and biotechnology. Lots of progress have been made in communication technology, space technology, etc. India is advancing in the area of knowledge and technology. Education thus has a very vital role in knowledge dissemination and the progress of society. Therefore, science responds to the needs and interests of the society in which it is practiced and developed.

Physical science includes the study of Physics and Chemistry. Physics is one of the most fundamental sciences. It deals with the study of matter and energy. The study of physics helps us to understand other sciences such as chemistry, biology, geology, astronomy, medical science, environmental science, and a host of other sciences. At the same time, the development of other sciences contributes to the development of physics itself. The connection between physics, technology and society can be appreciated by many examples. Sometimes technology generates new physics; at other times physics generates new technology. An example of this is the wireless communication technology that followed the discovery of the basic laws of electricity and magnet is in the 19^{th} century. The most significant are to which physics can contribute is the development of alternative energy resources. If nuclear fusion experiment is controlled to generate energy, it can bring prosperity to our society.

Chemistry is the study of properties and uses of matter. It is also one of the basic sciences and serves as the foundation for the understanding of biochemistry, molecular genetics, physics, geology, physiology, etc. Many new chemicals developed by chemists have important significance to society. To name a few, the book you are reading, the clothes you are wearing, the ink in your pen, materials for computers and mobiles, the life-saving medicines are all developed by the chemists.

Physical Science for Environment

The study of the effects of contaminants (physical, chemical, biological) on the environment has also become part of science. Scientists started working on the prevention of pollution of water, air, soil, noise, and that caused by radioactivity. For example, the use of Compressed Natural Gas(CNG) as fuel in preference to petroleum and diesel helps in reducing the level of carbon dioxide in the air. Also, alternative sources of energy such as

wind, solar, nuclear, biogas, tides, geothermal, etc. have been explored and their use is growing. These measures would surely decrease pollution and global warming. Ozone depletion has been checked largely by aerosols, such as Chloro Fluro Carbons (CFCs) so that they do not accumulate in the atmosphere. Suitable devices have been installed at the sites to map the noise pollution and to control it. Various measures have been employed in controlling radioactive pollution.

Thus, science is essential for the study of the environment and its improvement. A new branch of chemistry, green chemistry, has been developed to prevent the environment from degeneration. Green chemistry is about utilizing the existing knowledge and principles of chemistry and other sciences to reduce the adverse impact of human activities on the environment.

Physical science for Health

Science has served humankind to a great extent by making its members healthy and free from diseases. Physical science has contributed a lot in reducing human suffering by the discovery of anesthesia and antisepsis to be used for surgery and various medicines such as painkillers, antibiotics, sedatives, etc. to relieve pain and suffering.

Physical science for peace

Science has brought about an overall betterment of life of human kinds. Therefore, it is expected that if there is full collaboration in knowledge acquisition in pure and basic sciences and in the application of scientific knowledge to the developmental work, peace should rule on every aspect of the human psyche. Scientific knowledge is universal and it has no boundaries. The utilitarian side of science also has no conflict in serving society.

Children need to be encouraged to appreciate and participate in the responsible use of science and technology for the benefit of society.

Physical Science for equity

Science learning should be used as an instrument of social change to reduce the socio-economic divide. It should help fight prejudices related to gender, caste, religion and region. Science education ought to empower students to question the social beliefs, notions and practices that perpetuate social inequality.

Equitable educational systems foster the maximum development of individual potential. A commitment to equity ensures that all children have access to quality education; they develop knowledge and skills needed to participate effectively in community life as workers, citizens, parents, leaders and role models for future generations. To assure educational excellence for all students, schools must appreciate the diversity that students bring to the environment and organize schools and classrooms in such a way that the overall development of all students is ensured. Educational environments need to be created that honor diversity and respect of each individual. Equity helps to ensure that all students experience the highest levels of academic achievement possible, economic self-sufficiency and social mobility.

Researchers have shown that boys and girls perform equally well in science earning. Therefore, no gender bias should be practiced in the classroom and in allotting scientific work to the students.

Check Your Progress - 3

1. What is the contribution of physical science to society?
2. What is the contribution of physical science to the environment?
3. What is the contribution of physical science t health?
4. What is the contribution of peace to physical science?
5. What is the contribution of physical science for equity?

1.3.4. Let us Summarise

In this unit you have studied the following areas:

- Science is based on questioning and outcome based on following systematic procedure that is inquiry.
- All quantitative and qualitative results of science are due to systematic, keen and accurate observations made through science.
- Experiments are the basis of scientific knowledge experiments involves in the form of products of science.
- Physical science has interdisciplinary linkages with different school subjects as well as with the different science subjects. This helps us to teach science in a more unified/integrated manner which brings meaning to teaching and learning of physical science.
- Physical science as a discipline has progressed due to unquenched curiosity in men of science. So, it has the sole duty of societal concerns. It has benefitted every sphere of man's life and contributed a lot to the development of modern society.

1.3.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1. Observation. Its main purpose is to collect information and making quantitative and qualitative assessments. Five sense organs help us collect information (data) observation helps us to analyze the data and interpret it.
2. Scientific inquiry refers to finding an answer to the question in mind using various resources from surroundings to collect information, knowledge, data and idea. Scientific inquiry is important because it follows the usual set of procedures of scientific method defining the problem, setting hypotheses, design an experiment observing and recording data analyze and interpret it and firmly draw conclusions.
3. Experiments help in the following way:
    - They enhance learning
    - They satisfy the curiosity of the students
    - They develop ownership of learning science.
    - They help students to compare theory and practicals.

Check Your Progress - 2

1. A particular topic of physical science can be linked to other subjects to make its learning more meaningful. It is to link different subjects to bring the integration of subjects.
2. Examples
    i) Between science subjects
    Topic: defects of the eye

This topic can be taught in physical science. This can be linked to biology and physiology.

ii) Between science and History:

Topic: History of the earth is taught with the evolution of earth which is studied in science history of science will reveal about the development of science.

iii) Between science and geography:

Topic: Eclipse of Sun and Moon. It is a topic of both science and geography and the topics learnt in both subjects.

iv) Between science and languages

Topic: laws of refraction of light. This concept has to be learnt by students. They expected to explain it through writing. Then the role of the language comes. They should write clearly with appropriate language.

v) Between science and mathematics

Topic: Newton's II laws of motion

This topic requires both science and mathematics. An explanation has to be followed by a proper mathematical representation

Check Your Progress - 3

1. Responsible democratic citizenship development of scientific attitude science is an indispensable part of our lives.
2. Science has tackled problems like health population growth, safety from natural and human-induced disasters and infectious diseases and depleting natural resources endangered wildlife concerns etc.
3. Science has served human kinds to a great extent for making its members healthy and free from deceases. The Discovery of anesthesia and antiseptic have reduced human pain surgery.
4. Science both in its pure and applied form helps to bring peace and harmony. Scientific knowledge is universal and it has no boundaries. The utilitarian side of science also has no conflict in serving society.
5. Science learning as an instrument of social change to reduce semi economic divides. It should help fight prejudices related to gender, caste religion and region.

1.3.6. Unit end Exercises

I. Answer the following in about 3 pages:

1. Explain the significance of inquiry, observation and experimentation in physical science
2. Discuss the interdisciplinary linkages of physical science with other school subjects.
3. Discuss the interdisciplinary linkages of physical science with other science subjects
4. Bring out the uses of physical science with its societal concerns.
5. Write 5 examples each to prove physical science can be linked to (a) other school subjects and (b) other science subjects.

II. Answer the following in about a page:

1. What is the importance of inquiry in science learning?
2. What is the importance of observation in science learning?
3. What is the importance of experimentation in science learning?
4. How is physical science linked to history?
5. How is physical science linked to other science subjects?
6. What is the concern of physical science to society?

7. What is the concern of physical science with the environment?
8. What is the concern of physical science with health?
9. What is the concern of physical science with peace?
10. What is the concern of physical science with equity?

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Block 1 : Nature and Objectives of Teaching Physical Science

Unit 4 : History of Science / Physical Science

Unit Structure

1.4.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- understand the different civilizations' contributions to the advancement of science in the ancient period;
- identify how slowly and gradually scientific advancement progressed during the 14th and 15th centuries;
- recognize the steady increase in scientific progress after the 16th century;
- understand the rapid progress of science from the 17th century onwards;
- appreciate the hard work of scientists;
- realize scientists' contributions all over the world; and
- appreciate the contributions of Indian Scientists.

1.4.2. Introduction

"Science surpasses the old miracles of mythology" - Emersion

"History is the history of few people who believed in themselves". swami Vivekananda.

There were many philosophers like Socrates, Aristotle, Plato, who have explained different dimensions of life. Indian religious leaders like Buddha, VardhamanaMahaveera, Maharshi Aravindo, Ramakrishna Paramahamsa, Swami Vivekananda, Ramanamaharshi have projected light on different aspects of human life and its salvation.

There are writers, poets, dramatists, and others who have served for the good of society by releasing their literary talents through their expressions.

Like this, there are innumerable human achievements in different areas of knowledge who have contributed to human need and urge to satisfy themselves as well as society. Scientists, through the hard and unquenched, curious and systematic work have contributed to or unraveled many mysteries of nature. Millions of inventions have brought comfort to our

lives. It is very difficult to say when this journey of discovery commenced. But, are you not surprised by the greatest inventions of the unknown heroes? They are the invention of fire and the wheel – which are useful to us forever!

Science has influenced our way of thinking and way of living. It is because scientists and their hard work from time immemorial.

Activity:
List the names of scientists you have learnt with their contributions

In this unit, we will learn how science is developed as a fund of knowledge for many thousands of years. It is rightly said that the history of science has begun with the history of mankind.

1.4.3. Learning Points and Learning Activities

1.4.3.1. Science in the Ancient Period

History indicates Neolithic men of the New Stone Age were more advanced than Palaeolithic men of the New Stone Age. They knew agriculture and reared domestic animals, made houses and lived-in groups. The early homosapiens, probably discovered accidentally or by trial-and-error fire making, cooking and flint sharpening. They also discovered some processes like making earthen pots, weave baskets, build boats and houses, paint curves on flat surfaces, or use of metal for making arms and ornaments. Such abilities imply the use of science.

History reveals that human civilization began in Mesopotamia, Egypt and other places. They along with required skills acquired the art of writing the greatest attribute of science. Thus, the written record of the study of the movements of heavenly bodies, architectural designs, metallurgy, medicine, the methods of time telling, and the making of calendar justify this. In these two civilizations, the Sumerians, Babylonians and Assyrians and Egyptians made contributions in the area of science. Sumerians invented symbols and scripts for writing. Assyrians were better observers than Egyptians and able to use arithmetic and algebra. They could name the constellations taking the help of which the Egyptian priests could make annual calendars. Both Assyrians and Egyptians knew weighing and used balances and were familiar with ideas of mass, length and time. People of these two civilizations were good engineers and knew the techniques of making glass and glazes for pottery. There was also progress in the area of medicine and other branches of useful arts.

S. F. Mason in his book ‘history of science’ states that civilized society arises in India (around 3000B.C.) with Bronze Age culture in a river valley. This Indus valley civilization became extinct around 2000 B.C. Excavation in Mohenjo-Daro and Harappa (now in Pakistan) revealed a systematic order of town planning, a good drainage system and the use of kiln-fired bricks indicating high order of workmanship. There is no doubt that there were civilizations in China and India as old as Mesopotamian and Egyptian civilizations and they attained some degree of scientific development in different fields. The Indians are credited with the discovery of zero and the decimal system. The important names in Indian scientists are Aryabhata, Brahmagupta, Bhaskara, Varahamira in mathematics and Athreya in astronomy, Sushrutha and Charaka in medicine and surgery.

The advances in science progressed slowly during different civilizations as explained above. Later as the years passed people having curiosity to know and inclinations to find out new things emerged slowly. We can orderly place their names and contributions to the field of physical science century-wise as it helps you to understand the history of science (physical science).

Check Your Progress - 1

1. What were the discoveries of early homosapiens?
2. Who invented symbols and scripts for writing?

Who wrote the books philosophic naturals principia 'Mathematica' and 'optics'?

1.4.3.2. Contributions of Science From 16th to 21st Centuries

Contributions of Science in the 16th Century

Sl. No.	Year	Name of the Scientist	Discovery
1	1510	Da Vinci	designed the horizontal water wheel
2	1513	Peter Henlein	first portable pocket watch
3	1543	Copernicus	Earth was not the centre of the universe
4	1565	Conrad Gesner	A graphite pencil
5	1569	Gerardus Mercator	Mercator map projection
6	1589	William Lee	Knitting machine called the "Stocking frame.
7	1590	Zacharias Janssen	compound microscope
8	1593	Galileo	water thermometer
9	1600	Gilbert	Book on optics Magnet

Contributions of Science in the 17th Century

Sl. No.	Year	Name of the Scientist	Discovery
1.	1610-1634	Galileo	Wrote the book "Sidereal messenger". In a book on mechanics called Dialogue concurring to new concerning sciences". In 1632 he published a book called "Dialogue Concerning the Two Chief World Systems". Sun is the centre of the solar system (1632)
2	1571-1630	Johannes Kepler	planets revolve around the sun in ellipses and they move faster as they approach the sun
3	1668	Isaac Newton	Reflecting telescope Published his masterpiece "philosophic naturals Principia Mathematica". . In 1704 Newton also wrote a book on light called 'Optics'. Newton showed that white light is made up of several colours.
4	1629-1695	Christiaan Huygens	Titan, the moon of Saturn. In 1656 he made the first pendulum clock.
5	1661-1691	Robert Boyle	Wrote Book Skeptical Chemist, Modern chemistry. Boyle's law

Activity:
Read and collect information on the life histories of Galileo and Isaac Newton from the books and websites

Contributions of **Science in the 18th Century**

Sl. No.	Year	Name of the Scientist	Discovery
1	1751	Axel Cronstedt	Nickel
2	1752	Benjamin Franklin	Lighting is a form of electricity
3	1756	Joseph Black	Carbon dioxide
4	1766	Henry Cavendish	Isolated hydrogen and studied its properties
5	1772	Daniel Rutherford	Nitrogen
6	1774	Joseph Priestley	Oxygen
7	1743-1794	Antoine Lavoisier	Oxygen combines with substances. He also discovered the role of oxygen in respiration and corrosion of metals
8	1785	James Hutton	Theory of the Earth
9	1781	William Herschel	Planet Uranus
10	1784	John Goodricke	Variable stars
11	1800	Alessandro Volta	First chemical battery

Contributions of **Science in the 19th Century**

Sl. No.	Year	Name of the Scientist	Discovery
1	1808	John Dalton	Atomic theory Colour blindness
2	1819	Hans Christian Oersted	The electric current in a wire caused a nearby compass needle to move
3	1827	Friedrich Wohler	Isolated aluminum produced urea
4	1837	Louis Agassiz	On ice-covered northern Europe
5	1834-1907	Dmitri Mendeleev	Periodic Table
6	1847	Hermann von Helmholtz	Law of the Conservation of Energy
7	1854	John Snow	Cholera was transmitted by water
8	1822-1895	Louis Pasteur	Microscopic organisms caused disease
9	1873	James Clerk Maxwell	Light is an electromagnetic wave
10	1791-1867	Michael Faraday	Dynamo
11	1896	Henri Becquerel	Radioactivity
12	1797-1875	Charles Lyell	Formation of Rocks Principles of Geology
13	1898	Marie Curie Pierre Curie	Radium
14	1897	Joseph Thomson	Electron
15	1801	Giuseppe Piazzi	First asteroid, Ceres
16	1838	Friedrich Bessel	Measured the distance to a star
17	1846	Johann Gottfried Galle, John Couch Adams	Planet Neptune

Contributions of **Science in the 20th Century**

Sl. No.	Year	Name of the Scientist	Discovery
1	1862	Lord Kelvin	The age of the solar system, including Earth, was determined, and it turned out to be much older than believed earlier: more than 4 billion years, rather than the 20 million years suggested
2	1969	Apollo 11	was launched towards the Moon
3	1969	Neil Armstrong	the first person from Earth to walk on another celestial body
4	1957	Soviet Union	The first orbiting space probe, *Sputnik 1*, was launched
5	1903	Mikhail Tsvet	chromatography
6	1904	HantaroNagaoka	proposed an early nuclear model of the atom, where electrons orbit a dense massive nucleus
7	1905	Fritz Haber and Carl Bosch	Developed the Haber process for making ammonia, a milestone in industrial chemistry with deep consequences in agriculture.
8	1909	S. P. L. Sørensen	pH concept and develops methods for measuring acidity
9	1912	Peter Debye	Developed the concept of the molecular dipole to describe asymmetric charge distribution in some molecules
10	1913	Niels Bohr	introduced the concepts of quantum mechanics to the atomic structure by proposing what is now known as the Bohr model of the atom
11	1913	Henry Moseley	working from Van den Broek's earlier idea introduces the concept of atomic number to fix inadequacies of Mendeleev's periodic table, which had been based on atomic weight
12	1913	Frederick Soddy'	Radiochemistry
13	1913	J. J. Thomson	mass spectrometry
14	1916	Gilbert N. Lewis	The Atom of the Molecule
15	1951	Clemens C. J. Roothaan	Roothaan equations.
16	1970	John Pople	computational chemistry
17	1951	SumioIijima	electron microscopy

The development of post-Newtonian theories in physics, such as the Special theory of relativity, general theory of relativity, and quantum mechanics led to the development of nuclear weapons. New models of the structure of the atom led to developments in theories of chemistry and the development of new materials such as nylon and plastics. Advances in biology led to large increases in food production, as well as the elimination of diseases such as polio.

A massive number of new technologies were developed in the 20th century. Technologies such as electricity, the incandescent light bulb, the automobile and the phonograph, first developed at the end of the 19th century, were perfected and universally deployed. The first airplane flight occurred in 1903, and by the end of the century, large airplanes such as the Boeing 777 and Airbus A330 flew thousands of miles in a matter of hours. The development of television and computers caused massive changes in the dissemination of information.

Activity:
List the scientific advancements in the field of medicine

Contributions of Science in the 21st Century

Sl. No.	Year	Name of the Scientist	Discovery
1	1910	Ernest Rutherford	Atomic nucleus
2	1932	James Chadwick	Neutron.
3	1900	Max Planck	Quantum theory
4	1905	Albert Einstein	The special theory of Relativity
5	1915	Albert Einstein	General Theory of Relativity
6	1927	Werner Heisenberg	Uncertainty principle *and* speed of a subatomic particle.
7	1915	Alfred Wegener	Continental drift
8	1926	Arthur Eddington	Stars are powered by nuclear fusion
9	1920	Edwin Hubble	Our galaxy is only one of many galaxies
10	1930	Clyde Tombaugh	Pluto
11	1928	Alexander Fleming	Penicillin.
12	1964	Murray Gell-Mann	Quarks exist
13	1924-2018	Stephen Hawking	Black holes, relativity and cosmology

Check Your Progress- 2

1. Who found Radiochemistry?
2. Who devised dynamo?
3. Who discovered that light energy is a form of energy?

1.4.3.2. Famous Indian Scientists and their Inventions

Discoveries and studies in Science have been the result of the persevering efforts of scientists from different countries. In the past, many discoveries have been made in the field of Physics by Indian Scientists. After Independence, their contributions have been on the increase. A large number of our scientists have been working in various fields, including Physics, in various universities and research laboratories. From C. V. Raman to Salim Ali, the talents of Indian scientists and inventors have been fully established in many different areas, including physics, medicine, mathematics, chemistry and biology. Some of them have also contributed in a substantial way to advanced scientific research in many different regions of the world. Here is the list of famous Indian scientists and inventors throughout history and their wonderful contributions.

Sl. No.	Year	Name of the Scientist	Discovery
1	1861-1944	Prafulla Chandra Ray	Famous academician and chemist, known for being the founder of Bengal Chemicals & Pharmaceuticals, India's first pharmaceutical company.
2	1888-1970	C. V. Raman	The physicist who won the Nobel Prize in 1930 for his Raman Effect.
3	1909-1966	Homi Jehangir Bhabha	Theoretical physicist; best known as the chief architect of the Indian atomic energy program.
4	1858-1937	Jagadish Chandra Bose	Physicist, biologist and archaeologist who pioneered the investigation of radio and microwave optics.
5	1931-2015	A.P.J. Abdul Kalam	Known for his crucial role in the development of India's missile and nuclear weapons programs.
6	1922-2011	HarGobind Khorana	The biochemist who won the Nobel Prize in 1968 for demonstrating how the nucleotides in nucleic acids control the synthesis of proteins.
7	1893 – 1956	MeghnadSaha	An astrophysicist who developed the Saha equation, which explains chemical and physical conditions in stars.
8	1910 – 1995	Subrahmanyan Chandrasekhar	Astrophysicist won the Nobel Prize in 1983 for his research on the evolutionary stages of massive stars.
9	1893-1972	Prasanta Chandra Mahalanobis	Statistician and physicist who founded the Indian Statistical Institute.

Activity:
Encourage your student to read the life and achievements of Indian scientists and ask them to prepare posters and exhibit

Check Your Progress- 3

1. What is the discovery of Alfred Wegener?
2. Who is the Indian scientist called as the missile man?
3. Who started the first pharmaceutical company?

1.4.4. Let us Summarise

1. After going through the development of science in the past several decades that scientific advancement was very slow and gradually picked up its pace. It may be due to a lack of tools and techniques but not due to a lack of curiosity of men of science.
2. Their ability to attach themselves to the task on hand scientific venture is worth emulating. What may be the hardships faced by them to disprove the superstitions that existed then? (E.g.: Galileo Galilee) a lot of persistence exhibited by the scientists and passion they had are worth noticing.

3. After the 15th century, science could progress at a gradual pace. Now in the present age, we observe how science has occupied our life that it may not be possible to live without science and its applications.
4. Science is a never-ending venture. The present finding will be past finding in the future. Disproving some of the established knowledge and bringing genuine modification.
5. We all appreciate the contributions of scientists. They brought modernity to the whole world.

1.4.5. Answers to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1. fire making, cooking, flint sharpening, making earthen pots, weave baskets, build boats and houses, paint curves on a flat surface on use of metal for making arms and ornaments.
2. Sumerians
3. Isaac Newton

Check Your Progress - 2

1. Frederick Soddy
2. Michael Faraday
3. Benjamin Franklin

Check Your Progress - 3

1. Continental drift
2. APJ Abdul Kalam
3. Prafulla Chandra Ray

1.4.6. Unit end Exercises

I. Answer the following in about 3 pages

1. Describe in detail the development of science in the Ancient period.
2. Explain major advancements in science from the 16th century to the 18th century.
3. Physical science advanced well during the 19th and 20th centuries. Discuss.
4. Highlight the progress of physical science during the 21st century.
5. Bring out the contributions of Indian scientists.

II. Answer the following in about a page

1. What are the contributions during the ancient period?
2. How is the progress of science in the 16th century?
3. What are the major advancements in science during the 17th century?
4. How did science progress during the 18th century?
5. What are the major advancements of science during the 19th century?
6. How science augmented during the 20th century?
7. What is the leap in science during the 21st century?
8. Describe briefly the contributions of Indian scientists?

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Block 1 : Nature and Objectives of Teaching Physical Science

Unit 5 : Aims and Objectives of Teaching Physical Science

Unit Structure

1.5.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- explain the aims and objectives of teaching physical science;
- recognize the recommendations made by different National organizations related to physical science teaching;
- compare Bloom's taxonomy and Anderson and Krathwohl's taxonomy of educational objectives;
- observe the revised specific changes made in Bloom's taxonomy and Anderson and Krathwohl's taxonomy of educational objectives;
- realize the value of the application of taxonomy in the Planning and execution of science teaching at the secondary school level.

1.5.2. Introduction

In the previous unit, we have discussed the history of physical science which helped us to understand how physical science was evolved and accumulated. This unit will help you to understand the aims and objectives of teaching physical science. As a science teacher, it helps you to recognize how the aims and objectives of teaching physical science are derived based on the needs of society and children. Also, how the curriculum of science varies according to the age level of the children. You will be able to realize how educational taxonomies help in framing the objectives of teaching physical science. It can be observed from the study of this unit that the use of constructivism has gained momentum in the teaching physical science.

1.5.3. Learning Points and Learning Activities

1.5.3.1. Aims of Teaching Physical Science

Science teaches an understanding of natural phenomena. It aims to stimulate a child's curiosity in finding out why things happen in the way they do. It teaches methods of enquiry and investigation to stimulate creative thought. Children learn to ask scientific questions and begin to appreciate the way science will affect their future on a personal, national, and global level.

"Aim is a long-term goal".

"Science education will be strengthened to develop in the child well-defined ability and values such as the spirit of inquiry creativity, objectivity, the courage to question and an aesthetic sensibility" - NPE (1992).

The teaching and study of sciences aim to encourage and enable students:

- to provide the broader objectives of science that is process skill knowledge.
- to encourage and enable students to develop inquiring minds and curiosity about science and the natural world.
- to acquire knowledge, conceptual understanding, and skills to solve problems and make informed decisions in scientific contexts.
- to develop skills of scientific inquiry to design and carry out scientific investigations and evaluate scientific evidence to draw conclusions
- to communicate scientific ideas, arguments, and practical experiences accurately in a variety of ways
- to think analytically, critically and creatively to solve problems, judge arguments and make decisions in scientific and other contexts
- to appreciate the benefits and limitations of science and its application in technological developments
- to understand the nature of science and the interdependence of science, technology, and society including the benefits, limitations, and implications imposed by social, economic, political, environmental, cultural and ethical factors
- to demonstrate attitudes and develop values of honesty and respect for themselves, others, and their shared environment.

The aims of teaching physical science have undergone rapid changes during the last few decades. In the early days physical science was not considered a compulsory subject in schools. Only a few genius students opted to learn Physical Science. Importance was given to the teaching of scientific facts. Due to the development of science and technology science education was made compulsory not only in secondary schools but also at the elementary level as well.

The recommendations made by UNESCO's international commissions about the teaching of science and technology is as under:

"Science and technology must become essential components in any educational enterprise; they must be incorporated into all educational activity intended for children, young people and adults, to help the individual to control social energies as well as natural and productive one's thereby achieving mastery over himself, his choices and actions –and finally they must help man to acquire a scientific turn of mind so that he becomes able to promote science without being subjective for all the children in all the schools from primary to secondary level".

Thus, the aim of teaching physical science (1^{st} standard to S.S.L.C. 10^{th} standard) shifted from facts to the application aspect of science.

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

1. Connecting knowledge to life outside the school;
2. Ensuring that learning shifts away from rote methods;
3. Enriching the curriculum so that it goes beyond textbooks;

4. Making examinations more flexible and integrating them with classroom life; and
5. Nurturing an overriding identity informed by caring concerns within the democratic polity of the country.

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

It means science teaching should be provided to learners' experiences and opportunities should be provided to learners to explore the science around them. This marks a clear shift from classroom and laboratory centered science pedagogy.

Integration in science teaching-learning is very important and scientific knowledge should not be compartmentalized in subject domains like physics, chemistry biology, and environmental science up to the secondary level.

Science Education Should Enable the Learner To:

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

After going through the aims of teaching physical science at the school level, we find that knowledge of science plays a very important role in the progress of society. Like the product of science process of physical science has to be stressed in teaching. History of physical science has to be brought to the class which helps to know the development of science as well as the achievement and contributions of scientists the basis for it is unquestioned curiosity and imagination. Science leads to the development of a scientific attitude which results in the acquisition of values like intellectual honesty open-mindedness, objectivity . . . etc., Students must be made to learn about the environmental impact of science.

Check Your Progress - 1

1. What are the aims of science education according to NPE (1992)?
2. What are the guiding principles in curriculum development according to NCF (2005)?

1.5.3.2. Developing Learning Objectives of Teaching Physical Science

Dear students, we studied the aims of teaching physical science. They are broader goals of science education. Now let us concentrate on the objectives of teaching physical science.

Objectives are not only the goals towards which the curriculum is shaped and towards which teaching is guided but also provides the specification for the constructions and use of evaluation techniques.

Taxonomy of educational objectives is intended to provide for classification of the goals of our educational system. It is expected to help in the discussion of curricula and problems with greater precision.

In your previous teacher training (primary/elementary), you have already studied blooms taxonomy of instructional objectives which was implemented in the year 1956, Anderson and Krathwol proposed in their book "taxonomy for learning to teach and assessing: A revision of Bloom's taxonomy by removing the anomalies and giving more emphasis on verbs.

Bloom's Taxonomy and Anderson and Krathwol Taxonomy

Bloom's taxonomy is a classification of instructional objectives in a hierarchy. It is found quite useful in the communication of the objectives of a physical science lesson and also as a criterion for evaluation of physical science teaching

Bloom's taxonomy refers to the classification of the different objectives that educators set for students (learning objectives). There are identified domains of learning each of which is organized as a series of levels or prerequisites. It is suggested that one cannot effectively – or ought not to try to address higher levels until these below them have been covered. It also suggests a way of categorizing levels of learning, in terms of the expected ceiling for a given programme.

The taxonomy was first presented through the publication "The taxonomy of educational objectives, the classification of educational goals hard work I: Cognitive Domain" by Benjamin Bloom. **Bloom's taxonomy** is a set of three hierarchical models used to classify educational learning objectives into levels of complexity and specificity. The three lists cover the learning objectives in cognitive, affective and sensory domains.

a) Cognitive domain Objectives

We shall discuss the taxonomy which has two major dimensions namely;

1) Knowledge dimension and
2) Cognitive process dimension

Probably the most common educational objective is the acquisition of knowledge. The domain can be summarized as below:

1) The Knowledge Dimension

The new knowledge dimension contains four categories that are factual, conceptual, procedural and metacognitive knowledge involves knowledge about cognitive and awareness about one's cognition.

Table 1: Knowledge Dimension

a) **Factual Knowledge:** The basic elements that learners must know to be acquainted with a discipline or solve problems in it.
   - Knowledge of specifics
   - Knowledge of terminology

b) **Conceptual Knowledge:** The interrelationships among the basic elements within a larger structure that enable them to function together.
   - Knowledge of classifications and categories
   - Knowledge of principles and generalization
   - Knowledge of theories, models and structures

c) **Procedural Knowledge:** How to do something; methods of inquiry and criteria for using skills, algorithms, techniques and methods.
   - Knowledge of subject of specific skills and algorithms
   - Knowledge of subject-specific techniques and methods
   - Knowledge of criteria for determining when to use appropriate proceedings

d) **Metacognitive Knowledge:** Knowledge of cognitive in general as well as awareness and knowledge of one's cognition.
   - Strategic knowledge
   - Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
   - Self Knowledge

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

- Subject matter content (A noun or noun phrase)
- A description of what is to be done with or to that content (A verb or verb)

For example, a learner will be able to define 'work'. In this objective statement, the noun phrase is 'work' and the verb is define. In the original taxonomy (Blooms), noun and verb aspects were part of the knowledge dimension.

2) Cognitive Process Dimension

In the cognitive process domain, there are 6 categories, knowledge, comprehension, application, analysis, synthesis and evaluation. The categories are arranged in hierarchical order from simple to complex and concrete to abstract and also it was thought that attainment of one category is a prerequisite for the next category.

Dear students, let us observe and examine the **cognitive process dimensions** as described by Bloom and the revised taxonomy of Anderson and Krawthowl (2001). You observe the following table where the taxonomies are indicated.

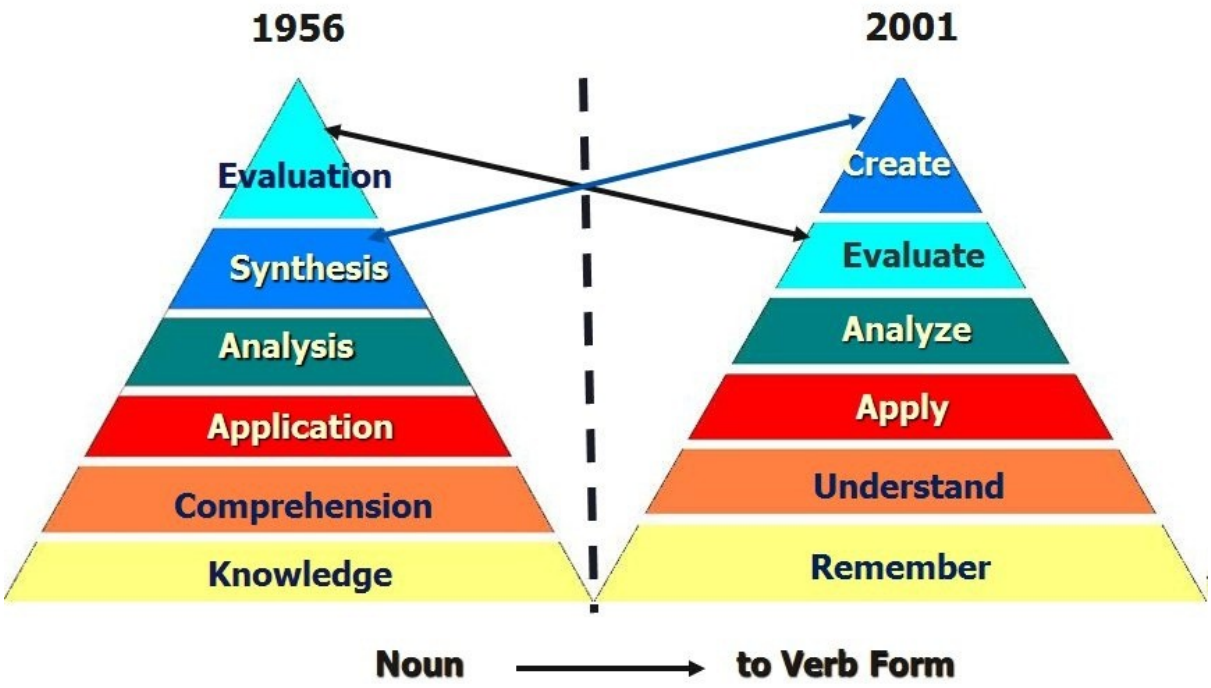


Table - 1

Objectives in Bloom's taxonomy and revised taxonomy of Anderson and Krathwohl

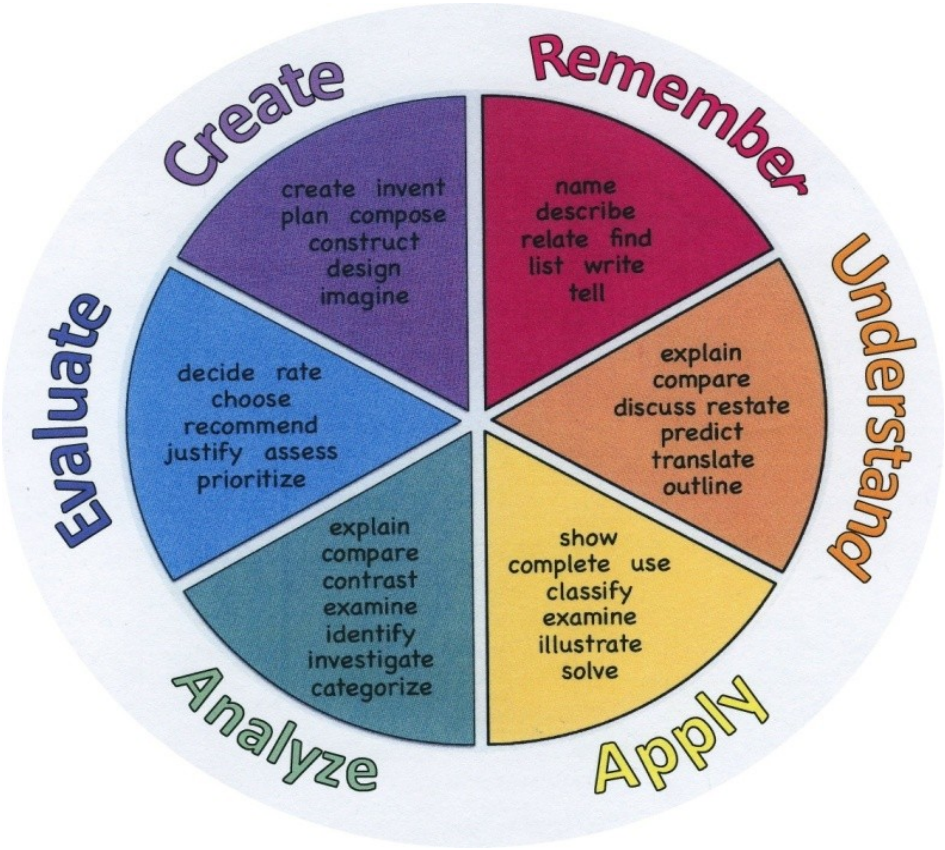
Activity - 1:
Observe the changes found in Bloom's taxonomy as well as the revised Anderson Krathwohl Taxonomy and list them.

We can observe the above table and see that the knowledge category is renamed as remember, comprehension is renamed as understand. Application analysis and evaluation are retained as verb forms i.e. apply analyze and evaluate. The evaluation was the last category in the original taxonomy but there it is 5th place (from below) and synthesis is replaced by a new category named as 'create' competencies of increase from below to above. The revised taxonomy reflects a more active form of thinking and is perhaps more accurate.

All these 6 categories are further divided into 19 subcategories and renamed as cognitive processes you can observe these cognitive processes below:

Remember	Understand	Apply	Analyse	Evaluate	Create
Recognizing	Interpreting	Executing	Differentiating	Checking	Generating
Recalling	Exemplifying	Implementing	Organizing	Critiquing	Planning
	Classifying		Attributing		Producing
	Summarizing				
	Inferring				
	Comparing				
	Explaining				

Table - 2



Comparison of Taxonomies of the Cognitive Domain

Bloom's Taxonomy 1956	Anderson and Krathwohl's Taxonomy 2001
1. Knowledge: Remembering or retrieving the previously learned material. Examples of verbs that relate to this function are: know identify relate list define recall memorize repeat record name recognize acquire	**1. Remembering: Recognizing or recalling knowledge from memory. Remembering is when memory is used to produce or retrieve definitions, facts, or lists, or to recite previously learned information.**
2. Comprehension: The ability to grasp or construct meaning from material. Examples of verbs that relate to this function are: restate locate report recognize explain express identify discuss describe discuss review infer illustrate interpret draw represent differentiate conclude	**2. Understanding: Constructing meaning from different types of functions, be it written or graphic messages or activities like interpreting, exemplifying, classifying, summarizing, inferring, comparing, or explaining.**
3. Application: The ability to use learned material, or to implement the material in new and concrete situations. Examples of verbs that relate to this function are: apply relate develop translate use operate organize employ restructure interpret demonstrate illustrate practice calculate show exhibit dramatize	**3. Applying: Carrying out or using a procedure through executing, or implementing. Applying relates to or refers to situations where learned material is used through products like models, presentations, interviews or simulations.**

4. Analysis: The ability to break down or distinguish the parts of material into its components so that its organizational structure may be better understood. . Examples of verbs that relate to this function is:

analyze compare	differentiate contrast	experiment
probe inquire	investigate detect	scrutinize discover
examine contrast	survey classify	inspect dissect
categorize	deduce	discriminate
		separate

4. Analyzing: Breaking materials or concepts into parts, determining how the parts relate to one another or how they interrelate, or how the parts relate to an overall structure or purpose. Mental actions included in this function are differentiating, organizing, and attributing, as well as being able to distinguish between the components or parts. When one is analyzing, he/she can illustrate this mental function by creating spreadsheets, surveys, charts, or diagrams, or graphic representations

5. Synthesis: The ability to put parts together to form a coherent or unique new whole. Examples of verbs that relate to this function are:

compose produce	plan invent	propose develop
design assemble	formulate collect	arrange construct
create prepare	set up generalize	organize originate
predict modify tell	document combine	derive write
	relate	propose

5. Evaluating:

Making judgments based on criteria and standards through checking and critiquing.

Critiques, recommendations, and reports are some of the products that can be created to demonstrate the processes of evaluation. In the newer taxonomy, evaluating comes

before creating as it is often a necessary part of the precursory behavior before one creates something.

6. Evaluation: The ability to judge, check, and even critique the value of material for a given purpose. Examples of verbs that relate to this function are:

judge assess	argue decide	validate consider
compare evaluate	choose rate select	appraise value
conclude measure	estimate	criticize infer
deduce		

6. Creating:

Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing. Creating requires users to put parts together in a new way, or synthesize parts into something new and different creating a new form or product. This process is the most difficult mental function in the new taxonomy.

Implications of Taxonomy

Bloom's taxonomy serves as the backbone of many teaching philosophies, in particular, those that lean more towards skills rather than content. These educators view content as a vessel for teaching skills. The emphasis on higher-order thinking inherent in such philosophies is based on the top levels of the taxonomy including analysis, evaluation, synthesis and creation. Bloom's taxonomy can be used as a teaching tool to help balance assessment and evaluative questions in class, assignments and texts to ensure all orders of thinking are exercised in students' learning, including aspects of information searching.

Activity - 2:

Select physics and chemistry topics from science textbooks of VII or IX standard. Try to formulate objectives using the above cognitive process dimensions.

b) Affective Domain Objectives

The next domain is the affective domain objectives. It is concerned with intents attitudes, adjustment, appreciation and values. The taxonomy consisted of five categories arranged in order of increased internationalization like the cognitive taxonomy. It assumed the learning at the lower category was a prerequisite to the attainment of the next higher one.

Here is the list of these categories from lowest to the highest in order of processes and behavior.

Level	Affective Domain Objectives	Behavior
1	**Receiving Attending** Without this level no learning can occur	Awareness Willingness to receive controlled or selected attention
2	**Responding** Attends to stimulus and reacts in some way	Acquiescence in responding willingness to respond satisfaction in response
3	**Valuing** Attaches value to an object phenomenon or piece of information	Acceptance of a value preference for a value commitment
4	**Organization** Krathwohl Bloom and Masia (1964) put together different values information, ideas and accommodate them in comparing, relating and elaborating or what has been learnt	Conceptualization of a value organization or a value mystery
5	**Characterization** Characterization by a belief or value or value complex that now exerts influence on his/her behavior	Generalized set characterization

Table - 3

Affective domain objectives typically target the awareness and growth in attitudes, emotions and feelings.

We stress in our education process, the development of soft skills. They are taken care of in this domain.

Dear students, it is observed that cognitive domain objectives play a significant role in our knowledge acquisition thinking and reasoning. No doubt about it. But, along with these, learners should also develop varied intents positive attitudes meaningful adjustment, appreciation of the surrounding world, and strong values. In the absence of it, an effort to educate learners may be a lopsided one. We should think of mind and heart development.

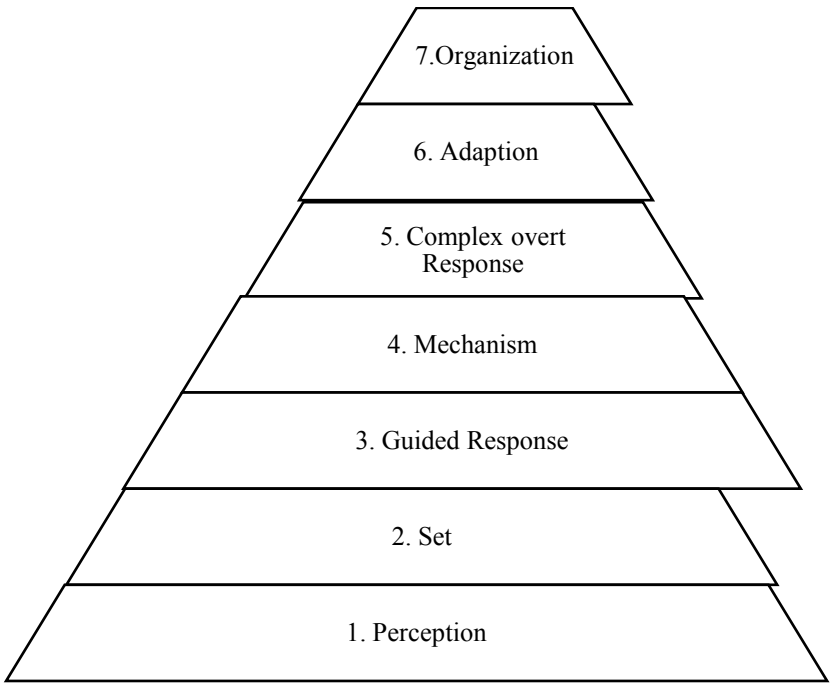
Activities for promoting affective domain objectives in Science class
• A selected science passage/science article (which is brief and specific) can be read in the class. Learners are instructed to listen carefully. You can frame some specific questions and pose them to the class to find a student's level of attention in listening.
• The life histories of scientists are elucidated in the class to create interest and appreciation of scientists and their hard work.
• Learners may be allowed to express as to what they value most in their life? And why? This helps the teacher to know them well and promote proper values.
• Teachers can teach with proper linkages in school subjects and between sciences. This helps students to understand and organize knowledge which results in value development.
• Teachers must always give a positive note of life incidents. This can be highlighting the success and struggle made by people who have achieved.
• You can try this in your classes. Ask learners to meditate by concentrating on their hearts for about 3 to 5 minutes and then teach them there will be an improvement in their learning?

c) Psychomotor Domain Objectives

We have learnt so far about the two domains of objectives Cognitive and Affective. The third one is psychomotor domain objectives

Psychomotor objectives usually focus on change and /or development in behavior and/or skills. One of the simplest version has been suggested by Dave, as well as Simpson and Harrow separately.

Simpson's model is suitable for the development of children and young people. Whatever the education and training situation, the psychomotor domain is significant. Below you find the psychomotor domain of Simpson.



Psychomotor Domain of Simpson

Level	Category / level	Description of behavior
1	Perception	Awareness
2	Set	Readiness
3	Guided Response	Attempt
4	Mechanism	Basic proficiency
5	Complex overt response	Expert proficiency
6	Adaptation	Adaptable proficiency
7	Organization	Develop and execute new integrated responses and activities

Table - 4

The above Psychomotor Domain objectives refer to the mind and hand coordination. They are essential in science teaching and learning. Psychomotor Domain (physical - skill - to do) is essential in modern-day education, business and social skills such as communication, operation of IT equipment, experiments, vehicle driving, public speaking etc. So, this domain is as important as the Cognitive and Affective domains. Hence, we need to concentrate on all three domain objectives while imparting education.

Check Your Progress - 2

1. What are the 6 cognitive process dimensions in Anderson and Krathwohl Taxonomy?
2. What are the similarities and differences between the cognitive domain of objectives in cognitive Bloom's taxonomy and the revised taxonomy of Anderson and Krathwohl?
3. Why should we encourage learners to listen with attention?
4. What is an organization? Why is it important?
5. Name the lowest level and highest level objectives in affective domain objectives.
6. Write any two limits of knowledge in the absence of values?
7. What are the different levels of the psychomotor domain?
8. Why psychomotor domain objectives are important?
9. Will experiments in the laboratory be examples of psychomotor skills? Why?

1.5.4. Let us Summarise

- The aim is a long-term Goal.
- According to NPE (1992), "Science Education will be strengthened to develop in the child well-defined ability and values such as the spirit of inquiry, creativity, objectivity, the courage to question and an aesthetic sensibility".
- According to UNESCO's International commission's recommendations is "Science and Technology must become essential components in any educational enterprise.
- NCF emphasizes on "Teaching of science should be recast so that it enables children to examine and analyze everyday experiences.
- Taxonomy of educational objectives is intended to provide for classification of the goals of our educational system.
- There are three domains of educational objectives – Cognitive, Affective and psychomotor.
- Regarding the cognitive domain, Benjamin Bloom (Original) and Anderson Krathwohl (Revised) have given different levels. Both have some common aspects as well as differences.

- In the cognitive domain, the 6 categories are knowledge, comprehension, application, analysis, synthesis and evaluation (Blooms).
- The new knowledge dimension has four categories – factures, conceptual, procedural and Metacognitive.
- Objectives in the revised taxonomy of Anderson Krathwohl are, remember, understand, apply, analyze, evaluate and create.
- All these six category are further divided into 19 subcategories.

1.5.5. Answer to 'Check Your Progress - 1, 2 3 and 4'

Check Your Progress - 1

1. The recommendation made by NPE (1992) on science education is that "science education will be strengthened to develop in the child well-defined ability and values such as the spirit of inquiry, creativity, objectivity, the courage to question and an aesthetic sensibility.

2. National Curriculum Framework (NCF – 2005) proposed five guiding principles for curriculum development. They are Connecting knowledge to life outside the school.

3. Ensuring that learning shifts away from rote methods; Enriching the curriculum so that it goes beyond textbooks; Making examinations more flexible and integrating them with classroom life, and Nurturing an overriding identity informed by caring concerns within the democratic polity of the country.

Check Your Progress - 2

1. The 6 cognitive dimensions in Anderson and krathwohl taxonomy are, remember, understand, apply, analyze, evaluate and create.
2. Knowledge and comprehension of Bloom's are taxonomy renamed as remember and understand in Anderson Krathwohl's taxonomy. Application, analysis and evaluate (verb form) in Anderson krathwohl's taxonomy evaluation was in last place (6^{th} place) in the Bloom's taxonomy but it is 5^{th} place from below in the Anderson – Krathwohl's Taxonomy as evaluate and synthesis are replaced by new category (create).
3. Because listening is the basis of all learning in many cases. Attentive hearing becomes the essence of good Comprehension.
4. We organize our learning only when it is comprehended properly. Long-term memory is possible by putting together all ideas information, comparing and elaborating etc. It enhances the learning of the content at hand.
5. The lowest level is receiving and the highest is characterization.
6. Knowledge without value is unworthy. It may be used to cause harm.
7. The different levels of the psychomotor domain are Perception, Set, Guided Response, Mechanism, Complex overt response, Adaptation and Organization.
8. Only developing cognitive and Affective objectives don't serve the purpose of education. Psychomotor stress on the development of skills that required mind and body coordination hence it is essential.
9. Experimental skills require doing with concentration. Hence it is an important skill for science students that come under a psychomotor domain.

1.5.5. Unit end Exercises

I. Answer the following in about 3 pages

1. Discuss in detail the importance of the aims and objectives of teaching physical science.
2. Explain Bloom's taxonomy of educational objectives.
3. Explain Anderson Krathwohl's revised taxonomy of educational objectives compare and differentiate it with Bloom's Taxonomy.
4. Explain the different levels of Affective domain objectives.
5. Explain the different levels of psychomotor domain objectives as given by Simpson.
6. Why is the need to stress affective and psychomotor objectives in the modern education system? Explain.

II. Answer the following in about a page

1. What are the aims of teaching physical science?
2. What are the objectives of teaching physical science?
3. What are the dimensions of teaching physical science?
4. What are the objectives of the cognitive domain given by Bloom?
5. How are the objectives of Anderson different from Bloom's cognitive domain?
6. What are the different levels of the affective domain of objectives?
7. Write the different levels of psychomotor objectives given by Simpson?

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Block 1 : Nature and Objectives of Teaching Physical Science

Unit 6 : Instructional Objectives in Teaching Physical Science

Unit Structure

1.6.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- understand the purpose of writing instructional objectives in the teaching of physical science.
- understand the importance of educational objectives;
- explain the meaning of instructional objectives;
- explain the meaning and importance of different objectives of teaching physical science;
- recognize the criteria in the selection of instructional objectives;
- understand the method of writing instructional objectives;
- write instructional objectives to specific topic/content.

1.6.2. Introduction

Dear students, the main purpose of human life is to attain salvation. To attain it we plan certain objectives in our lives and hence find the answer to the following questions. Such as what makes our lives happy and comfortable? What makes our life worthy/fruitful? What makes our lives healthy?

We answer the above questions and think of making our lives happy and comfortable, worthy and healthy. We will be geared towards the ultimate attainment of happy comfortable, fruitful and healthy lives. This is achieved by everyday efforts continuously. Thus, we may move to the highest attainment that is salvation.

Likewise, we have a purpose of teaching physical science for example development of scientific culture. To attain this, we frame the aims of physical science teaching at different levels of education. Next, we frame general objectives to physical science teaching at

different levels of education and in the end, we think of instructional objectives for each class of physical science teaching. All these instructional objectives in each science class will lead to the development of the general objectives at different levels. Thus, after certain education students are imbibed with the scientific culture. Hence, attainment of this is a long process and needs efforts and time by the teachers of science at all levels of education.

Dear students observe the following details

Purpose of teaching physical science

Aims of teaching physical science

General objectives of teaching physical science

Instructional objectives of teaching physical science.

Students, you have learnt in detail the Aims of physical science teaching as recommended by various educational committees. These general aims are further spelt as objectives of teaching physical science in particular.

The whole educational system is directed to achieve the aims of science and physical science. For a science teacher, it is not possible to achieve those aims immediately at a point in time. The total summated programme should generate a force to achieve these aims. The part of the aims specifically drawn by the school to achieve these aims of science is called objective. The teacher keeps the objectives in view structuring the instructional activities. The term objective is defined as “an end view of the possible achievement in terms of what a student can do when the whole system is directed towards the aim”. Thus objectives are the set of achievable events in pursuit of an overall aim.

Physical science as content and the process-oriented subject has a unique way of expressing objectives. The three dimensions of Bloom’s taxonomy can be abundantly availed to frame the instructional objectives of physical science. A physical science teacher has to know the way of writing instructional objectives by using General objectives like knowledge, understand, Application, Skills, Interest, Attitude, Appreciation, Talent and Concern for the environment. Let us concentrate on the instructional objectives in physical science.

1.6.3. Learning Points and Learning Activities

1.6.3.1. Meaning, Purpose, types of Writing Instructional Objectives and Objectives of Teaching Physical Science

Instructional objectives are in measurable terms that describe what learners will be able to do after the instruction. It is essential to have clearly outlined instructional objectives to make sure that what is taught in the course matches the intended outcome. An instructional process becomes successful when a well-organized list of instructional objectives is prepared.

The main purpose of instructional objectives is:

1. To provide direction for the instructional process by clearly stating the intended learning outcomes.
2. To convey instructional intent to pupils, parents and educational organizations.
3. To provide a basis for evaluating pupil learning by describing the performance to be measured.

Types of Instructional objectives:
Instructional objectives in the teaching-learning process can be divided into two types:

a. General Instructional Objectives:

It is a goal or intended learning outcome stated in general enough terms. It includes a set of specific objectives in it.

b. Specific Learning Objectives:

A goal or aim serving as a guide for a teaching unit, directed toward the eventual achievement of a general objective. It is stated in terms of specific and observable pupil performance. It describes the specific behaviour, a learner will exhibit after learning a particular unit. Let us discuss separately different criteria for stating, general instructional objectives and specific learning objectives.

The first step of effective teaching is to clearly define the designed learning outcomes. It also helps us to develop a good evaluation procedure. Instructional objectives play a pivotal role in the teaching-learning process.

Kinds of Instructional Objectives

Instructional objectives are often classified according to the kind or level of learning that is required to reach them. There are numerous taxonomies of instructional objectives; the most common taxonomy was developed by Benjamin Bloom and his colleagues. The first level of the taxonomy divides objectives into three categories: cognitive, affective, and psychomotor. Simply put, cognitive objectives focus on the mind; affective objectives focus on emotions or affect, and psychomotor objectives focus on the body.

Cognitive objectives call for outcomes of mental activity such as memorizing, reading, problem-solving, analyzing, synthesizing, and drawing conclusions. Bloom and others further categorize cognitive objectives into various levels from the simplest cognitive tasks to the most complex cognitive task. These categories can be helpful when trying to order objectives so they are sequentially appropriate. This helps to ensure that prerequisite outcomes are accomplished first.

Affective objectives focus on emotions. Whenever a person seeks to learn to react appropriately emotionally, there is some thinking going on. What distinguishes affective objectives from cognitive objectives is the fact that the goal of affective objectives is some kind of affective behavior or the product of an affect (e.g., an attitude). The goal of cognitive objectives, on the other hand, is some kind of cognitive response or the product of a cognitive response (e.g., a problem solved).

Psychomotor objectives focus on the body and the goal of these objectives is the control or manipulation of the muscular-skeletal system or some part of it (e.g., dancing, writing, tumbling, passing a ball, and drawing). All skills requiring fine or gross motor

coordination fall into the psychomotor category. To learn a motor skill requires some cognition. However, the ultimate goal is not the cognitive aspects of the skill such as memorizing the steps to take. The ultimate goal is the control of muscles or muscle groups.

Understanding Educational Objectives **(Bloom's Taxonomy, 1956)**

From the point of Teaching physical science, we need to understand the Educational objectives of teaching it. Therefore, the explanation of them is given below:

a) **Knowledge:** Knowledge is the acquisition of information i.e., scientific information. It is considered a major objective and occupies a major part of the educational objectives. Knowledge is nothing but gathering or accumulations of information of the external world through our sensory organs.
It does not guarantee to understand; hence, it is the first level of learning.

b) **Understanding**: When the knowledge acquired through sense organs, gets digested in a meaningful way we call it is understood. When it is grasped comprehended, arranged, rearranged, analyzed, synthesized, compared, differentiated, applied ……. We call it is understood. It may be evaluated and used to create new means of dealing with knowledge.

c) **Applications:** Knowledge that has been digested and understood needs to be applied to new/novel or unfamiliar situations in daily life. This may include rules. methods, laws principles theories, etc. It requires a lot of higher-level learning.

All the above three objectives come under the cognitive Domain.

d) **Interests**: When students show a willingness to learn the subject, we can say they are interested to learn it. It is concerned with bringing holding and directing the student's concentration and attention to the subject. Learning outcomes in this objective range from simple awareness that the thing exists to selective attention on the part of the students. It becomes the duty of the science teacher to develop an interest in the students.

e) **Attitude:** Scientific attitudes are the most important outcomes of science teaching.
"An attitude is a psychological constituent or latent variable, inferred, observable responses to stimuli which are assumed to mediate consistently and constituency among these responses".

Thurstone and Chave define attitude as "Sum total of man's inclination and feelings, prejudices and bias, preconceived notions, fears, threats and convictions about anything. In other words, attitude is what you 'feel' and opinion is what you 'express'.

f) **Appreciation:** The basic aim here is to give students a real feel and admiration of science. This is concerned with the worth or value a student attaches to a particular object, phenomenon or behavior. This ranges in degree from the simpler acceptance of a value to the more complex level of commitment. Appreciation is based on the internalization of a set of specific values but includes those values which are expressed in the students' over behavior.

The above 3 objectives Interest, Attitude and appreciation come under the affective domain.

g) **Skill:** This is concerned with the use of sense organs to obtain levels that guide motor activity. This includes physical, mental and emotional aspects of students. It includes imitation, practice, error, perfection of a skill.

The skill has to be developed and practiced with confidence and proficiency. Proficiency is indicated by quick, smooth and accurate performance requiring minimum energy.

The students of science are expected to develop the following skills.

1. General skills
2. Drawing skills
3. Experimental skills
4. Construction skills
5. Computational skills

h) **Talent:** Identifying scientific talents in the students is another objective. This can be done by observing their class activities and performance.

Science talents include writing science articles, preparation of charts and models conducting experiments, improvising equipment etc.

i) **Environmental concern:** As students of science they should develop concern for the environment. Preservation and conservation of the environment is the need of the hour. Science has contributed so much to the progress of mankind. Pollution is the result of the mishandling of science. Students must learn to prevent it.

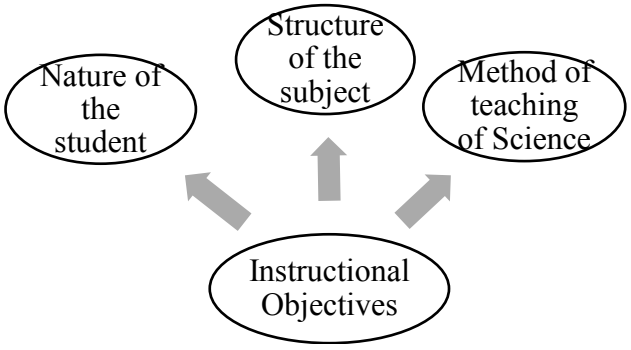
Thus while developing the educational objectives the following points are to be considered.

1. The needs and abilities of the learner.
2. The needs of society and its expectations.
3. The nature of the subject matter.

The objectives form the basis for creating learning experiences and framing appropriate evaluation tools. Following are the criteria for the realization of objectives.

- Objectives are to be framed based on aims.
- They should be specific and precise in terms of means, ends and time frame.
- They should be relevant and useful.
- They should describe the behavioral outcome.
- They should be observable, measurable and attainable.

The teacher has to keep the following points while formulating instructional objectives.



Objectives of Teaching Physical Science

The objectives of teaching physical science according to various recommendations of NCERT may be summarized as under:

- To explore the immediate environment of the student.
- To observe, record, report accurately in oral, written and graphic form.
- To collect information from various sources and use them in a given situation.
- To classify objects, events, phenomena…..
- To arrange objects and data in a sequence to ascertain a pattern.
- To analyze data and make an inference.
- To find cause-effect relation from data available.
- To make predictions.
- To design simple experiments.
- To solve problems.
    - To develop an objective attitude towards experimental evidence and to make decisions based on facts and data.
    - To understand the role of Indian scientists in the development of science.
    - To make judicial use of national resources after their proper identification.
    - To be careful to avoid any wastage of natural resources and take the necessary steps for the prevention of pollution.
    - To correlate the knowledge of science and technology to the economic and social development of the community.
    - To emphasize scientific knowledge in everyday life.
    - To make proper use of scientific knowledge for the development of desired social and moral values.
    - To develop the scientific attitude, the spirit of cooperation, scientific temper and scientific approach.

Activity:
You have studied the way of writing instructional objectives in your previous course. List some of them you have used while writing instructional objectives.

Instructional objectives are the expected terminal performance of the individual student at the end of the period of learning. An instructional objective is written in the form of a statement that describes what the student will do or will be able to do, once instruction has been completed. It is a learning product that the teacher hopes will result from instruction.

What can be achieved by a teacher within the normal class period with the help of various resources available to him by the teaching of a particular lesson is called instructional objective.

Though the writing of such an objective will differ from topic to topic and situation to situation, yet format remains the same.

The instructional objective is those objectives that are set up in the process of teaching and learning as endpoints. Thus it tells that what a student is going to learn or achieve after a period of instruction. According to Hurter (1970) “An instructional objective is an ability or skill expressed in behavioural forms which the students acquire or develop when the teaching

has been successful in doing what is set out to do". Therefore the main objective of education is to modify the student's behaviour.

Check Your Progress - 1

1. What are the objectives of teaching physical science?
2. What are instructional objectives?
3. Which are the 3 points to be kept while framing instructional objection?
4. What are the main objectives of education?

1.6.3.2. Criteria in Selection of Instructional Objectives

Selecting Specific Objectives

In selecting specific objectives, various criteria may be used because the more limited an objective is the more likely that it can be attained within the allotted time.

Thurber and Collette have suggested the criteria for selecting educational objectives as Instructional objectives and they are.

a) **Usefulness:** The knowledge acquired and understanding developed must be useful to the learners in their social life.
b) **Timeliness:** Learning should be concerned with material familiar at present and not with absolute desire and ideas.
c) **Fitness:** The learnt knowledge must fit into a sequence that leads the learner to achieve his aim.
d) **Appropriateness:** The learning called for should be appropriate to the maturity and backgrounds of the learner and the societal needs.
e) **Practicability:** The learner must be able to make use of the learnt material in practicable situations.

According to Dr. R.C Sharma, a good objective should be.

a. Specific
b. Unambiguous
c. Useful
d. In accordance with the general aims of education
e. Feasible
f. Attainable
g. Measurable and
h. Observable

Writing S.M.A.R.T. Objectives

To be effective, instructional objectives should be:

1. **Specific.** Instructional objectives should precisely describe what is expected of a learner. For example, the learner will be able to deal with irritable customers, which is not a specific objective. This could be made better by stating how the learner will deal with the irritable customer.
2. **Measurable**. A measurable instructional objective is one that can be observed or one that generates data points. For example, the learner will apply compassion skills to handle irritable customers and log and report the outcome of each call by the end of the month. The learner's log offers data about how the customers reacted to the technique.
3. **Attainable:** Learners cannot feel defeated by the intended outcomes of the learning objectives. Instructional objectives should not ask learners to prove themselves under

unfeasible circumstances. Give learners ample time to prove their new skills. For example, in the objective above, the learner has one month to prove he or she is effectively exercising the new skills. This is ample time for the learner to do so.

4. **Relevant:** Most learners do not care about learning things that they cannot use right away. The information presented in the course and the outcomes should be relevant to their personal lives or day to day work.
5. **Time-framed:** Learners need a deadline for when they should achieve and demonstrate the use of the skillset. One month is the time-frame for the objective mentioned above. A learning objective that is not time-framed gives learners the false impression that they have an indefinite amount of time to learn the skill and apply it.

Activity: 2

- Encourage your students to think over for about 10 minutes and write what science-related information they have collected from (other than textbooks) various sources of information.

- How you as a teacher help your students to be aware of the importance of protecting this environment? List some of the measures you take up.

Check Your Progress- 2

1. What are the educational objectives of teaching physical science?
2. List the criteria for selecting specific objectives.
3. Name some of the qualities of a student possessing a scientific attitude and scientific interest.

1.6.3.3. Writing Instructional Objectives

You have already learnt about the different objectives of teaching physical science. Now we write them in terms of Instructional objectives.

R.F. Magerin his book "Preparing instructional objectives" has suggested three steps of writing performance objectives.

Decide what the learner should be doing when the instruction is given:

For example – Recall, Recognise, identify, compare, contrast, define, Describe examine derive, Determining, Director, Discarnate, Hypothesise, interpreted, Generalise, verify …….

Decide under what conditions the behavior is developed:

After determining the behavior to be changed for an objective of Instruction, it is obvious to consider with what condition that behavioral change occurs and indicate it.

Decide what will be the expected …….. Performance.

Performance objective must indicate that "how well" or "how best" the learner is expected to perform at the end of the instruction.

For example – the learner should be able to classify convex and concave lenses when several lenses are given together.

As students of science, you have already studied about Aims and objectives of Teaching physical science in the previous Unit (5). There is a detailed explanation of them. Still, from the clarification purpose, there is a need for you to learn the objectives in other words revisit the objectives as we have to think of writing instructional objectives in this Unit.

Here, we write instructional objectives by writing General objectives and the related specific objectives,

i) Knowledge

General Objectives

To enable the students to acquire knowledge of scientific terms, scientific facts, and scientific concepts, scientific laws, scientific principles, procedures in the field of physical science.

Instructional Objectives

To enable the students to

a) Recall the scientific terms, facts, concepts, laws, principles, produces.
b) Recognize the scientific terms, facts, concepts, lams, principles, procedures.

ii) Understanding

General Objectives

To enable the students to acquire an understanding of scientific terms, scientific facts, scientific concepts, scientific laws, scientific principles, procedures in the field of physical science.

Instructional Objectives

To enable the students to

a) explain facts, concepts, principles and phenomena.
b) define facts, concepts, principles and phenomena.
c) describe the concepts and phenomenon.
d) compare two concepts.
e) Contrasts two concepts.
f) verbalize symbolic relationships.
g) substitute numbers to symbols and formula
h) verify the results.
i) use appropriate units.
j) identify the sequence in a process.
k) identify errors.
l) rectify errors.
m) judge adequacy of data.
n) find the difference between an opinion and a fact.
o) interpret the given data.
p) generalize given data.

iii) Application

General Objectives
To enable the students to apply knowledge and understanding in physical science to new or unfamiliar situations.

Instructional Objectives
To enable the students to
a) give reasons for a process
b) explain causes for an effect
c) formulate a hypothesis.
d) verity hypothesis.
e) establish cause-effect relationships.
f) suggest experimental procedures.
g) make interpretations.
h) suggest measures for improvisation of equipment.
i) devise new procedures.

iv) Skills

General Objectives
To enable the pupils to acquire scientific skills in the field of physical science.

Instructional Objectives
To enable the students to
a) plan the procedure of arranging the apparatus
b) select and check the apparatus.
c) measure objects accurately
d) read scientific equipment
e) take precautions while using the equipment.
f) substitute values to numbers and numbers to value
g) compute
h) tabulate values properly
i) write figure and graphs properly
j) use proper symbols and notations
k) solve problems in an order accurately

v) Interests

General Objectives
To enable the pupils to develop scientific interests in the field of physical science.

Instructional Objectives
To enable the students to
a) read scientific literature
b) collect charts, models of science
c) seek pleasure in solving problems.
d) select science projects.
e) discuss science projects.
f) prepare charts and models.

vi) Appreciation:

General Objectives
To enable the pupils to develop a scientific appreciation in the field of physical science.

Instructional objectives:
To enable the students to
a) recognize the need for accuracy, brevity, logical coherence
b) realize the beauty of science
c) appreciate the contributions of scientists
d) realize the importance of science in our lives.

vii. Attitude:

General Objectives
To enable the students to develop a scientific attitude in the field of physical science.

Instructional objectives
To enable the students to
a) suspend judgment till proper evidence is obtained
b) have clarity and brevity in the statement made
c) judge without bias
d) show a willingness to reconsider the interpretation
e) have validity in statements
f) reject belief in superstition
g) accept only logically established ideas
h) report result without manipulation
i) accept his mistakes without hesitation
j) have open-mindedness
k) not to accept any conclusion as final

Activity: 3
Select a unit of Physical science and list as many educational objectives as possible.

Writing Instructional Objectives to Specific Concept – Energy and Potential Energy
1. recall the general meaning of work and energy in daily life: the meaning of work in physics.
2. recognize the meaning of energy and potential energy.
3. define energy and potential energy.
4. illustrate the energy and potential energy through suitable examples.
5. identify variation in potential energy when the height and mass of the bodies vary.
6. use "mgh" to represent potential energy.
7. calculate potential energy when mass and height are given.
8. identify the uses of potential energy in daily life.
9. prepare a simple apparatus to demonstrate the potential energy of a body.
10. appreciate the use of potential energy in our life.
11. to verify the increase in potential energy as the height & mass of the body increase.
12. have the interest to check that strain in the body increases potential energy.

Activity: 3
Indicate in the table given below under which objectives these specifications are hinted number wise

Objectives	Serial Number of Specifications
Knowledge	
Understanding	
Skill	
Interests	
Attitude	
Appreciation	

Activity: 4
Write instructional objectives to a specific 'topic' from Physical science.

Check Your Progress- 3

1. What may be the reason for adding scientific talent and environmental concerns as educational objectives?
2. What are the Instructional objectives under the general objective of 'Knowledge'?
3. If recall and recognize are lowe- levels objectives, list two higher-levels of objectives.
4. Name two scientific skills.

1.6.3.5. Revised Blooms Taxonomy of Educational Objectives (Anderson and Krathwohl's taxonomy)

The following chart gives the Revised Blooms Taxonomy of Educational Objectives given by Anderson and Krathwohl w.r.t Cognitive domain.

Chart adapted from Anderson, L.W., Krathwohl, D.R. (2001). *A taxonomy of learning, teaching, and assessing*. Boston: Allyn and Bacon. Also from the Center for University Teaching, Learning, and Assessment, the University of West Florida and the Center for Teaching and Learning, University of Texas.

Level	Level Definition & Attributes	Action Verbs	Example of Learning Outcomes
Level 1: Remember	Students exhibit memory of previously learned materials by recalling facts, terms, basic concepts, and simple answers.	choose, define, find, how, label, list, match, name, omit, recall, relate, select, show, spell, tell, identify, describe, copy, locate, recognize, memorize, quote, reproduce, tabulate, discover, duplicate, listen, enumerate	By the end of this course, students will be able to recite Newton's three laws of motion.
Level 2: Understand	Students demonstrate an understanding of facts and ideas by interpreting, exemplifying, classifying,	classify, compare, contrast, extend, demonstrate, explain, illustrate, infer, interpret,	By the end of this course, students will be able to explain the causes of

	summarizing, inferring, comparing and explaining main ideas.	outline, relate, rephrase, show, summarize, select, translate, describe, paraphrase, ask, differentiate, discuss, express, distinguish, restate, group	Pollution
Level 3: Apply	Students solve problems in new situations by applying acquired knowledge, facts, techniques and rules differently.	calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, build, construct, develop, experiment with, identify, make use of, organize, plan, select	By the end of this course, students will be able to calculate the kinetic energy of a projectile.
Level 4: Analyze	Students can examine and break information into parts by identifying motives, causes and relationships. They can make inferences and find evidence to support a generalization.	classify, outline, break down, categorize, analyze, diagram, illustrate, assume, compare, conclusion, contrast, discover, dissect, distinguish, divide, examine, function, inference, inspect, list, motive, relationships, simplify, survey, take part in, test for	By the end of this course, students will be able to analyse the parts of a Dynamo
Level 5: Evaluate	Students can present and defend opinions by making judgments about information, the validity of ideas, or the quality of work based on a set of criteria. They can justify a decision or course of action.	design, formulate, build, invent, create, compose, generate, derive, modify, develop, agree, appraise, assess, award, choose, compare, conclude, criteria, criticize, decide, deduct, defend, determine, disprove, estimate, evaluate, explain, influence, judge, interpret, justify, mark, measure, perceive, prioritize, rate, recommend, rule on, select, support, value	By the end of the course, students will be able to assess the different ways of generating electricity.
	Students can compile, generate or view information, ideas or products together in a different way by combining elements in a	adapt, build, change, choose, combine, compile, compose, construct, create, delete, design, develop, discuss, elaborate, estimate,	By the end of this course, students will be able to design and execute synthetic and analytical experimental procedures found in the scientific

	new pattern or by proposing alternative solutions.	formulate, happen, imagine, improve, invent, makeup, maximize, modify, originate, plan, predict, propose, solve, suppose, test, hypothesize, substitute, compile, develop, rearrange, anticipate, assemble, collaborate, collect, devise, imagine, intervene **Revised Blooms Taxonomy of Educational Objectives (Anderson and Krathwohl's taxonomy**	literature in physical and inorganic chemistry.

Check Your Progress - 4
Explain the different levels of revised Blooms Taxonomy of Educational Objectives

1.6.4. Let us Summarise

- Instructional objectives are the expected terminal performance of the individual students at the end of the period of learning.
- Educational objectives include knowledge, understanding, Application, skills, interests, attitudes, appreciation, talent and concern for the environment.
- While framing Instructional objectives nature of the students, structure of the subject and need of the teaching of the subject is to be kept in mind.
- Criteria of Instructional objectives are usefulness, timeliness, fitness, appropriateness, practicability.
- Characteristics of a good objective are specific, unambiguous, useful, measurable, observable, flexible, and attainable and in accordance with the general aims of education.
- Educational objectives are further spelt specifically as instructional objectives.
- Writing instructional objectives for a specific topic requires spelling the instructional objectives related to the topic.

1.6.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1. Objectives are the set of achievable ends in pursuit of the overall aim.
2. Instructional objectives are the expected terminal performance of the individual student at the end of the period of learning.
3. Nature of the students, structure of the subject, method of teaching of science.
4. It is to bring about a modification of student's behavior.

Check Your Progress - 2

1. Usefulness, timeliness, fitness, appropriateness, practicability, It should be specifics useful, feasible, attainable, measurable observable and in accordance with the general aim of education.
2. Knowledge, understanding, applications, skills, interests, attitude, appreciation, talent and environmental concerns.
3. Open-mindedness, rejecting authority, suspended judgment etc scientific interests are listening to scientific lectures and preparation of science models.

Check Your Progress - 3

1. Creation from the learner is an indication of creativity saving the environment is the primary concern of every human being.
2. Recall and recognize.
3. Classify and differentiate concepts.
4. Select the instrument appropriately
5. Measure the instrument accurately.

Check Your Progress - 4

Refer Section 1.6.3.4.

1.6.6. Unit end Exercises

I. Answer the following in about 3 pages

1. Why do we write the instructional objectives?
2. Explain in detail the educational objectives
3. Explain the instructional objectives of teaching physical science.
4. Select a topic from physical science and write all specific objectives.
5. Why you as a teacher need to nurture the scientific talents of students?
6. How you as a teacher do create awareness of the environment and preserve it?
7. Explain the Cognitive domain Revised Blooms Taxonomy of Educational Objectives with appropriate examples from Physics.

II. Answer the following in about a page

1. Write the meaning of instructional objectives
2. What is the purpose of writing instructional objectives
3. List the different educational objectives in physical science.
4. What are the points to be considered while developing educational objectives?
5. What are the criteria in the selection of instructional objectives?
6. Write specifications under understanding objectives.
7. Write instructional objectives for a selected topic from physical science.

1.6.7. References

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 1 : Science Process Skills
Process of Learning through Observation, Inquiry, Hypothesis, Experimentation, Data Collection, Interpretation and Generalization

Unit Structure

2.1.2 Learning Objectives

After completing learning this Unit, the student teachers will be able to

- Understand the meaning and importance of Science Process skills;
- recognize the meaning of the process of learning through observation, inquiry, hypothesis, experimentation, data collection, interpretation and generalization;
- identify observation as the basic science process;
- realize the importance of inquiry in science learning;
- recognize the hypothesis is a tentative solution to the problem;
- use experimentation to prove/disprove hypothesis;
- justify the importance of data collection for scientific proof;
- find the way or method of interpreting the data;
- realize how the proof/evidence/data leads to generalization;
- find the use of process skills in the learning science; and
- understand the importance of developing the process skills (used by scientists) in secondary school students.

2.1.1. Introduction

In this block 1, of course, 7: Physical Science we studied 'nature and objectives of teaching Physical Science. In this Block, we will study the Approaches and strategies of learning Biology/physics.

Teaching must proceed in a child-centered way and the teacher plays the role of a facilitator. There is a need to be learning based on activities. To comprehend the knowledge and acquire understanding along with the required skills of learning science, various approaches and strategies are to be used by the teachers. Before using them teachers must help students to understand the intricacies of the process of learning science. (Basic as well as

integrated skills). They are observing, measuring, classifying inquiring, Hypothesizing, Experimentation, Data collection, interpreting and generalizing. Because, these are the very essence of science learning, students need to acquire basic science process skills that are used by scientists to do science. They are observing, classifying, communicating, measuring, estimating, predicting and inferring. You may find some more advanced process skills sometimes referred to as integrated skills like identifying and controlling variables, hypothesizing, interpreting data, defining operationally, experimenting and constructing models.

At the secondary level, your focus should remain on developing basic science process skills among students.

In this unit 1 of Block 2, you will learn the basic and some of the integrated process skills of science.

2.1.3. Learning Points and Activities

2.1.3.1. Science Process Skills: Meaning, Importance and Process of Learning through Observation

Science Process Skills: Meaning and Importance

The history of science is in part the history of how scientists came to look at the world they study. Scientific experimentation and observation have come to be defined by the exercise of a process called the *scientific method*. The underlying skills and premises which govern the **scientific method** are referred to as science process skills.

Science process skills refer to the following six actions, in no particular order: observation, communication, classification, measurement, inference, and prediction. These basic skills are used in the experiments of scientists and students, as well as in the everyday life of an average person, to a degree. They allow everyone to conduct an objective investigation and to reach conclusions based on the results.

Science process occurs naturally, spontaneously in our minds. By logically breaking down the steps in our thinking, we can use the science process as to how to answer our questions about how the world works. Science process is not only useful in science, but in any situation that requires critical thinking.

Process of Learning through Observation

Observing means using our various senses to obtain information (or data) about objects or events attended.

Albert Bandura claims that children continually learn desirable and undesirable behavior through observational learning. Observational learning suggests that an individual's environment, cognition, and behavior all incorporate and ultimately determine how the individual functions and models.

Bandura's social cognitive learning theory states that four factors influence observational learning:

1. **Attention:** Observers cannot learn unless they pay attention to what's happening around them. This process is influenced by characteristics of the model, such as how much one likes or identifies with the model, and by characteristics of the observer, such as the observer's expectations or level of emotional arousal.
2. **Retention/Memory:** Observers must not only recognize the observed behavior but also remember it at some later time. This process depends on the observer's ability to code or structure the information in an easily remembered form or to mentally or physically rehearse the model's actions.
3. **Initiation/Motor:** Observers must be physically and/intellectually capable of producing the act. In many cases, the observer possesses the necessary responses. But sometimes, reproducing the model's actions may involve skills the observer has not yet acquired. It is one thing to carefully watch a circus juggler, but it is quite another to go home and repeat those acts.
4. **Motivation:** The observer must have the motivation to recreate the observed behavior.

Observation is not to be limited to seeing things only. We use more than one sense organ to collect data (or information) about our daily acts. Actions like looking at a rainbow, feeling vibrations of tongs of tuning fork by touching, smelling the fragrance of Jasmine flower, listening to change in volume and pitch of a musical instrument and tasting honey – involve observation using one or the other sense organs.

A teacher in the class was teaching the concept of "dispersion of light". She wrote a figure of it on the blackboard and explained the formation of it. Later she could hold prism to sunlight through the window and could show fascinating colors of dispersion of light on the ceiling of the classroom. The whole class could stand up with astonishment. This is the value of observation.

In the class, students should be made to observe equipment's/materials like a microscope, thermometer, mirrors, lenses, specimens, and collect information to learn. Students who observe experiments in the class and laboratory (while doing) have ample opportunities to state their observations carefully.

You as a teacher will ask your students to fill in the table, to indicate what they observe in the following situations/ activities:

Activity	**What all they observe?**	**Senses involved in the observation**
Outside our home		
Watching a bird		
In the laboratory		
Watching an aquarium		
Cooking in the kitchen		

When students complete their work, the teacher will ask them to “define observation” based on their observation.

By getting a response from them, the teacher will specify the characteristics of observation.

Observation has the following characteristics:

1. It explains what the activity is and how it takes place.
2. It is a continuous process.
3. Random observation may not be fruitful. In scientific investigation, students should be given background information to draw the required and essential details.
4. It is essential to limit what is to be observed.
5. It helps to describe what is to be observed.
6. Human memory may fail if data is retrieved very late. Hence, there is a need to record the observation as it is in a notebook.
7. Observation must take place under certain conditions.
8. It is important to have some hypothesis in mind before making observations.
9. Scientific observation may be quantitative. Qualitative statements also play an important role type of observation depends on the object of the investigation.
10. The observation which depends on human senses may use instruments as aids. Much of nature can be observed with the naked eye, but more accessible when instruments are used.
11. It is both qualitative and qualitative. When a rectangle-shaped object is shown to the students they observe its shape, color, material and texture (qualitative) and different dimensions like length and breadth, height, volume, weight (quantitative) of the object.

Activity

As a teacher you plan some of the activities for observation and instruct students to write examples for the following:

- Observation involves many senses
- Observation is both qualitative and quantitative

Students, so far you have studied how important it is to use observation in science to acquire data. This process will be processed by registering, classifying, generalizing etc. and converting it to knowledge. Our mind sorts out the information based on differences and places into various categories based on similarities, which later on can be recalled for use in different situations, thus becoming a part of knowledge.

Here you can notice that knowledge is constructed by the individual by applying his / her mental abilities. It depends on the individual’s ability to observe and his / her intelligence to process information. Individuals in the same environment may possess different levels of knowledge. The basic unit of knowledge is a fact. Any repeatedly verifiable observation becomes a fact.

Examples:

1. The rainbow is always seen in a direction opposite to that of the sun.
2. A ball rolling on any surface comes to stop after some time.

Activity: Write some more examples of Observable scientific facts.

Metal, Acid, Solid, Water, Glass, Paper, Pen, Chair, Molecule, mixture, salt, Solution, Combustion, evaporation, Oxidation, Waves, interference, X-ray, semiconductors etc. are examples of concepts. Thus, a concept is a word, an idea or a mental image of an object, process or phenomenon.

A student is said to have learned or attained the concept, if he/she can give examples of the concept learned and also can differentiate non-example, For example, ice is a non-example of a liquid, and common salt is a non-example of an acid. She/he can list the characteristics of the concept and can define the concept based on its characteristics.

Direct experiences and observations are essential for the formation of many concepts. Each individual has to interpret natural phenomena in terms of her / his own experiences.

Learner's environment and prejudices may affect concept formation. Sometimes much time lapses between the original experiences and the development of the concept and its application.

Many concepts can be combined in a way to convey the meaning which can be tested and verified universally. Then they become a principle.
Example:

- Metals expand on heating
- Liquids evaporate on heating
- Archimedes principle
- Bernoulli's principle.

A Principle is a comprehensive generalization describing a property related to a natural phenomenon. The principle is based on concepts that are formed through concrete examples. People apply these principles to understand the realities around them, to explain the phenomena they have observed and to test their hypothesis in laboratories.

Classification is another basic science process skill, itis a process of imposing order on the collection of objects (or events) based on similarities, differences and interrelationships. Such classification helps us to organize our observations to convey some meaning. Students are to be trained to classify things/objects/ events based on some specific criteria. They can be helped to group the object based on its color, size, shape, length, volume, weight etc. Like this, they also need help to organize different concepts of science-based on specific criteria.

For example, they can classify conductors and insulators, scalars and vectors, magnetic and nonmagnetic substances and so on.

Activity: Classify the following as scalars and vectors

Length, straight line, mass, distance, displacement, volume, velocity, speed, density, acceleration, force, work, momentum.

Measurement

Like classification, measurement is also a basic process skill. What we observe in science has to be quantitatively expressed through measurement; we help students to measure length, volume, mass, weight, temperature and time in our classes. It helps procure quantification of data resulting from our observation and experimentation. We can encourage the student to measure entities by using standard scales and instruments such as rulers, meter rods, balances, graduated cylinders, calculators, stopwatches, thermometers and electrical instruments etc. to bring precision in measurements. You can also help students to select suitable units to express or compute the data by converting one unit into another and even expressing conventional units into metric units. For example converting meters to kilometers, miles to meters and so on.

Activity: Measure the linear dimensions of your school and school playground in meters and feet. Compare them.

Communication

What has been measured in science has to be communicated accurately to others. Students must be trained to communicate what they have observed and measured properly. Students communicate their learning with teachers, friends in group situations as well as individual situations. This communication may be verbal or non-verbal. Science has its way of communicating through scientific vocabulary.

Check Your Progress - 1

A. Fill up the blanks by using the suitable word:

1. Science process is not only useful in science, but in any situation that requires _____.
2. Observation means using our senses to obtain _____ data.
3. Observation is both qualitative and quantitative.
   Quantitative aspect includes _____
   Qualitative aspects includes _____

B. Write answer to the following questions:

1. What is a fact? Give one example.
2. What is a concept? Give one example.
3. What is a principle? Give one example.
4. What is the process of classification and measurement?

2.1.3.2. Process of Learning through Inquiry, Hypothesis, Experimentation and Data collection

An inference is an explanation based on observation. It is a link between what is observed and what is already known.

Examples:
The learner will write a conclusion at the end of each investigation.
The learner will create inferences about observations they made about a mystery object. I infer it is solid rather than hollow.

Inquiry-learning includes:

- Creating questions of their own.
- Obtaining supporting evidence to answer the question(s).
- Explaining the evidence collected.

- Connecting the explanation to the knowledge obtained from the investigative process.
- Creating an argument and justification for the explanation.

There is however certain features of science that give it a distinctive character as a mode of inquiry. Although those features are especially characteristics of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in everyday life. Curiosity is the centre of inquiry. Students learn through inquiry which begins with some incidents.

The first element of inquiry is an event the individual can react to and puzzle over a problem to be solved.

Example:
When a stick is immersed in a beaker containing water (half-filled) appears to be bent. Why it is so?
The teacher asks students to reflect on it. Students started discussing by giving explanations for their observations.
The responses were different.
Some said water has something which makes the stick bend.
Some said it is magic.
Some said there is something in the stick.

The very first process is the construction of an explanation. But you as a teacher may not accept these explanations of students as a scientific explanation. But it starts like this. Scientific explanations must always be based on evidence. But as a teacher you must encourage them for generating explanations based on their observation and previous scientific knowledge.

To encourage students

- You have to pose appropriate questions.
- The questions should be testable.
- The answers to these testable questions are called hypotheses (tentative solutions to the problems).
- Plan, observe and conduct investigations
- Construct explanations and communicating results.
- What students should do in the inquiry process?
- Students must be helped to develop an awareness of the problem and a desire to solve them.
- Students must assume the dual roles of participant and observer, simultaneously. inquiry into the problem and observing themselves as inquirers.
- Students must follow the conscious method so that they may collect data, associate and classify ideas recalling past experiences, formulate and test the hypothesis, study consequences and modify plans. Hence, students need to be trained in the inquiry.

Activity: Plan, how you will investigate and solve a problem through the process of inquiry.

Process of Learning through Hypothesis

A **hypothesis** (plural **hypotheses**) is a proposed explanation for a phenomenon. For a hypothesis to be a scientific hypothesis, the scientific method requires that one can test it.

A good hypothesis fits the evidence and can be used to make predictions about new observations or new situations.

- **Hypothesis in Science**: A provisional explanation that fits the evidence and can be confirmed or disproved. In science, a hypothesis must be falsifiable, meaning that there exists a test whose outcome could mean that the hypothesis is not true. The hypothesis must also be framed before the outcome of the test is known.

Steps to Create a Hypothesis

A hypothesis statement begins with a simple idea. It takes three steps to write a hypothesis:

1. Ask a question.
2. Gather background information.
3. Form the hypothesis.

Hence, a hypothesis is a probable solution or tenability is to be tested on the grounds of compatibility of its implications with empirical evidence and with previous knowledge. A good hypothesis should explain data in simpler terms and should be stated as consciously as possible.

The observation of a phenomenon, or facts, raise certain question such as what caused it to happen? Or why did it happen this way and not in another way? Based on the answers to these questions, the scientist thinks of a tentative explanation or formulates a hypothesis. Suppose you switch on the circuit make it closed and the bulb will not glow, then you have a question in mind that why the bulb did not glow? Then you will test the bulb for its working condition, the wire for its conduction, the battery or cell for its remaining storage of energy and the switch for its working. These entire hypotheses are testable. One correct solution is accepted. One of the most important features of science is that it requires a hypothesis to cast into a form that can not only be verified but significantly proved to be wrong.

Process of Learning through Experimentation,

Experimentation is the process of performing a scientific procedure, especially in a laboratory, to determine something.

An experiment is a procedure carried out to support, refute, or validate a hypothesis. Experiments provide insight into cause-and-effect by demonstrating what outcome occurs when a particular factor is manipulated. Experiments vary greatly in goal and scale but always rely on repeatable procedure and logical analysis of the results.

Prediction of science does not mean telling something about the future which has not occurred in the past. It is about foretelling the results of an experiment that might be obtained and have remained or not remained unnoticed to throw some light on the scientific phenomenon. The hypothesis is analyzed to make predictions that are verifiable by

experimentation. If experiments show that the hypothesis formulated is not correct, the new hypothesis is formulated and subjected to experimental verification. A hypothesis can make more than one prediction. Such a hypothesis is accepted only when all the predictions made by it have been confirmed by experimentation.

It is difficult to conceive a science programme without experimentation. In secondary schools, science teaching experiments and laboratory work are almost synonyms. Most of the laboratory work particularly investigatory laboratory experiences involve experimentation. It ranges from a simple act of inquiry activity to an exceedingly complex act of problem-solving. Experiments may include both controlled experiments and also laboratory exercises. In an open-ended laboratory experiment, the endpoint of the experiment is unknown to the students whereas in verification type of experiments the end prints are known to the students.

Activity: Let students find the linear expansion of metal strips by using a source heat by keeping it for a fixed time.

Process of Learning through Data Collection

Data collection is the process of gathering and measuring information on targeted variables in an established system, which then enables one to answer relevant questions and evaluate outcomes.

Importance of **Learning through** data collection:

1. Data empowers you to make informed decisions
2. Collecting data allows to store and analyze important information.
3. Data helps you identify problems
4. Data allows you to develop accurate theories
5. Data will back up your arguments
6. Data makes your approach strategic
7. Data helps you get your hands-on funding
8. Data tells you what you're doing well
9. Data saves you time
10. Data increases your return on assets
11. Data improves the quality of life

After framing the hypothesis they need to be tested for their validity, experimental evidences are to be given based on which hypotheses are to be either accepted or rejected in the height of evidences. Tentative solutions are accepted in the presence of proper evidences. Data has to be collected through experimentation or verification. If they found the evidences go against the tentative solution, then it is rejected. The most suitable solution to the problem is considered.

From all possible sectors, the relevant information should be collected by the students. They should be clear about the problem to be investigated. They collect relevant information from all possible sources. They can consult the experts, references and evidences having a bearing on their problem. Teachers must be skillful in guiding students to develop a variety of skills and techniques. Many devices like experiments, filmstrips, textbooks, models, grades, and websites are to be used by the students in locating information. Mechanical errors and personal errors are to be avoided at the time of collection of data. Data has to be accurate and valid in order to bring out proper generalization.

Activity: Make students collect information on the use of solar energy in a locality and write their interpretation on it.

Check Your Progress - 2

Answer the following questions:

1. What is the role of students in inquiry process?
2. Which is a good hypothesis?
3. Specify the role of experimentation. How are open-ended experiments and verification type experiments differentiated?
4. How is data collected by students?

2.1.3.3. Process of Learning through Interpretation and Generalization

Process of Learning through Interpretation

Interpretation is the act of explaining the meaning of something. Interpretation is a communication process, designed to reveal meanings and relationships of our cultural and natural heritage, through involvement with objects, artifacts, landscapes and sites. Interpretation is the act of communicating information understandably. It is not a laundry list of important facts but rather a means to share with people basic ideas that can enhance how they experience their surroundings. Interpretation is important as it leads to the establishment of explanatory concepts.

Interpretation is the most important, vital and at the same time a difficult step. It demands reflective thinking, complex skills and abilities. It requires a lot of practice and patience. The students should be asked to analyze the evidence to find out if there are any similarities and differences in the results.

The process of observation and construct patterns, explanations and interpretations are for further understanding. The skill of interpretation to a great extent is closely related to the skill of inferences.

When we interpret an experience, we explain the meaning it has for us. It is a process of putting meaning into and making meaning out of our experiences. Interpretation involves describing a given situation and then explaining the meaning one has received.

Classification of Interpretation

Sl. No.	Aspects	Example
1	Those that are reasonably sure	The occurrence of day and night
2	Those which are probably true and those that seen to have some hunches	Occurrence of rain
3	Those drawn by different types of reports	Reports on population Reports on Air pollution
4	To add meaning, read between the lines, to fill in gaps and to extend the information	Reports on women empowerment
5	To understand reports in numerical, pictorial, graphic and literary styles.	Reports of global warming
6	It can interpolate and extrapolate the data	Reports on women scientists.

Process of Learning through Generalization

Generalization is the concept that humans and animals use past learning in present situations of learning, if the conditions in the situations are regarded as similar. The learner uses generalized patterns, principles, and other similarities between past experiences and novel experiences to more efficiently navigate the world.

The process of formulating and verifying a hypothesis continues till all the predictions of a hypotheses/ hypothesis are found to be corrected by experimentation. At this stage, possible generalizations of the hypotheses/hypothesis are looked for. The results are communicated to be the scientific community through publications in scientific journals. The results are then open to experimental scrutiny by scientists all over the world.

Students in the class are to be encouraged to draw generalizations based on the evidence of the hypothesis of a hypothesis. They need to judge the consistency or uniformity or harmony of the generalization in the light of tested evidence. When a hypothesis is sustained or kept by logical tests, it provides the basis or ground for generalization or conclusions.

Thus the process of learning science has to be stressed by the teacher of science as it helps students to be mini researchers. This training may lead them to be true researchers in their later life.

Activity: Plan an experiment, let students conduct it and generalize results.

Check Your Progress - 3
Answer the following

1. Specify the purpose of the interpretation of data.
2. What is the purpose of generalization?

2.1.4. Let us Summarise

- Science process occurs naturally, spontaneously in our minds.
- Observing means using our various senses to obtain information (or data) about objects or events attended.
- Observation is both qualitative and quantitative.
- The process of observation involves registering, classifying generalizing etc and converts it to knowledge.
- The basic unit of knowledge is a fact. Any repeatedly verifiable observation becomes a fact.
- The concept is an idea or mental image of an object, process and phenomena. A student is said to have learned or attained the concept, if he/she can give examples of the concept learned and also can differentiate non-examples from examples of the concept.
- Many concepts can be combined in a way to convey then they become the principle. A principle is a comprehensive generalization describing a property related to a natural phenomenon.
- Classification measurement and communications are also important in science processes.
- An inquiry has curiosity at the centre.

- A hypothesis is a probable solution for the problems at hand. A good hypothesis should explain data in simpler terms and should be stated as consciously as possible.
- Experimentation ranges from a simple act of inquiry activity to an exceedingly complex act of problem-solving.
- Based on the experimenting hypothesis is verified. Based on data collection, the hypothesis is either accepted or rejected.
- When we interpret an experience, we explain the meaning it has for us.
- Generalization is the last step in scientific inquiry. When a hypothesis is accepted, it is kept open for scrutiny. It is accepted by all.

2.1.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

A. Fill up the blanks

1. Critical thinking
2. Information
3. Length, volume, size, (quantitative) and Shape, color, material & texture (Qualitative)

B. Write answer to the following questions,

1. Any repeatedly verifiable observation becomes a fact.
   An example is "The rainbow is always seen in the direction opposite to that of the sun".
2. Concept is a word, an idea or a mental image of an object, process or phenomena.
   An example is "Respiration".
3. A principle is a comprehensive generalization describing a property related to a natural phenomenon.
   An example is the "Archimedes Principle".
4. Classification is a process of imposing order on the collection of objects (or events) based on similarities, differences and interrelationships, measurement is the precise quantification of data.

Check Your Progress - 2

1. Students must have awareness of the problem and curiosity to solve it. They assume the dual roles of participant and observer. They have to collect data, associate and classify ideas, recalling past experiences, formulate and test hypotheses, study consequences and modify plans.
2. A good hypothesis should explain data in simples terms and should be stated as consciously as possible.
3. Experimentation involves discovering the relationship between two variables that depend on one another. Experiments may include both controlled experiments and also laboratory exercises.
4. In Open-ended laboratory experiments, the endpoint of the experiment is unknown to the students, whereas in verification-type experiments the endpoints are known to the students.
5. Students can collect data by using experts. References, evidence having a bearing upon their problem, many devices like experiments, filmstrips, textbooks, models, graphs, websites are to be used by students in collecting data. Data has to be valid & accurate to bring out proper generalizations.

Check Your Progress - 3

1. This is the most important, vital 7 difficult steps. The students should be asked to analyze the evidence to find out if there are any similarities and differences in the results, when we interpret an experience, we explain the meaning it has for us. It is a process of putting meaning into and making meaning out of our experiences.
2. The process of generalization is there when a hypothesis is accepted or rejected. The results are communicated to the scientific community through publications in scientific journals. Students should be trained to develop the skills of generalizing the results of the experiment.

2.1.6. Unit end Exercises

A. Answer the following questions in about 3 pages:

1. Why are the science process skills important? Explain the process of learning through observations.
2. Describe the process of learning through Inquiry.
3. What are hypotheses? Why are they framed? Explain with one example.
4. "Experiment is the basis of Science learning" justifies this statement through the examples (any4).
5. What is data collection? Why is it needed in science learning? Explain the different sources of data collection.
6. "The various evidence obtained are to be interpreted properly" justify this.
7. Explain the process skills of Science? Why is generalization important?

B. Answer the following in about a page:

1. What is observation? Explain briefly the types of observation.
2. How to train students in Inquiry?
3. Write the meaning of a hypothesis. What is the variable in it?
4. What are open-ended laboratory experiments and verification type experiments?
5. How do you as a teacher help your students to collect data?
6. What is an interpretation of data?
7. Explain the procedure you would use to develop science process skills.

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 2 : General Overview of Different Approaches and Strategies of Teaching Physical Science

Unit Structure

2.2.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- recognize the different approaches and strategies of teaching physical science;
- identify the components of the teaching learning process;
- differentiate an approach and a strategy;
- recognize the constructivist approach and the 5 E model;
- understand the stages of problem-solving approach;
- identify the importance of concept map with examples;
- recognize the possibilities of cognitive conflict;
- list the essential features of the inquiry approach;
- recognize how teacher help students to learn through self-study strategy;
- mention the uses of analogy strategy in teaching; and
- understand the alternative approaches and strategies of teaching physical science.

2.2.2. Introduction

Dear Students, in the previous courses you have already studied teacher-centered and learner-centered approaches and strategies of Teaching & Learning. List some differences between them.

Sl. No.	Teacher Centred Approaches	Learner Centred Approaches
1		
2		
3		
4		
5		
6		

You have listed some differences between them. In teacher-centered approaches and strategies, the teacher transmits the facts and assumes the students a passive receptor of knowledge and they learnt what is taught to them. On contrary, learner-centered approaches pay much attention to the learner and his learning. NCF 2005 emphasizes the learner-centered approach to achieve the objective of the curriculum. The curricular contents and its transaction must be relevant to the learners and should help them to become constructors of knowledge and lifelong learners. Therefore, **a pedagogical shift is required from the teacher-centered to learner-centered teaching-learning process.** There is a need to move from a predetermined set of outcomes and skills to the set that enables learners to develop explanatory reasoning, critical thinking and inquiry skills.

In this unit 2 of block 2, you will have an overview of different approaches and strategies for teaching physical science.

2.2.3. Learning Points and Learning Activities

2.2.3.1. Effective Components of Teaching-Learning Process

Approaches and strategies of learning help us to decide how to initiate a learning process to engage learners; how to transact the concept and what teaching-learning materials can be selected to make transactions enjoyable and learning meaningful. Studies show that different learners have different learning styles and learn differently. They come to the class with some prior knowledge about the natural world around them. Therefore, a teacher has to consider various approaches and strategies of learning to cater to the learning needs and learning styles of all learners.

Teaching-learning of science is a very complex process. This process involves learner, teacher, teaching-learning materials, suitable approaches and strategies and conducive learning environment leading to meaningful learning. The learner is at the centre of the learning process and the teacher works as the facilitator of learning. Figure 1.0 represents the components of the Teaching learning process.

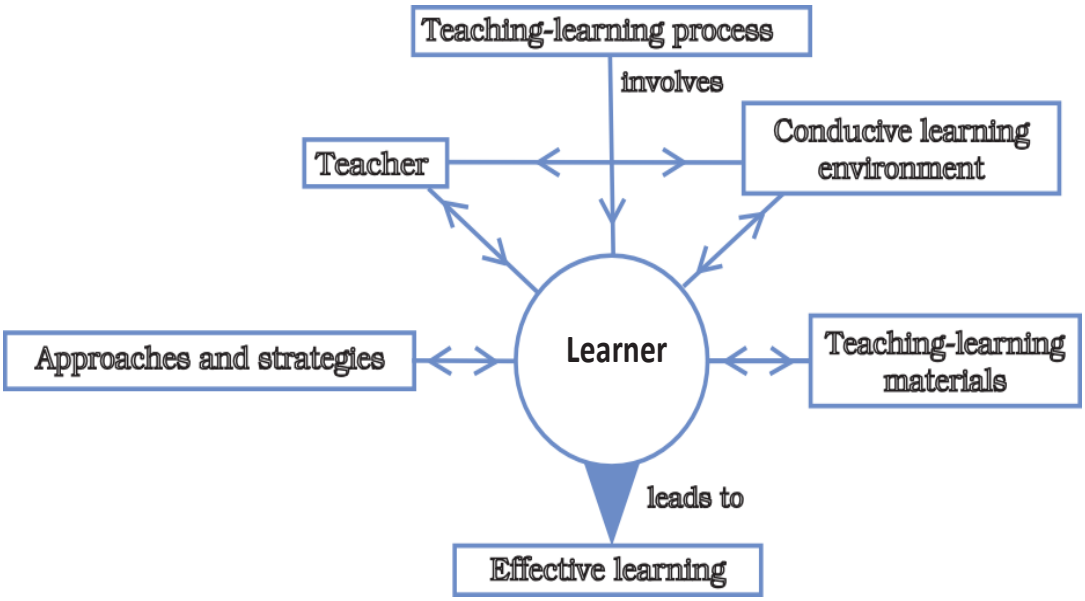


Figure 1: Teaching-learning process

Difference between an Approach and a Strategy

An approach is used in the broader sense. It means a way of thinking and working in a set direction to accomplish certain goals. On the other hand, the strategy is a proper and systematic plan which aims to achieve the objectives. In education, strategy means the selection of suitable pedagogical processes using appropriate techniques, such that all of those lies in the realm of the approach, the teacher chooses to follow. There is no best approach or strategy of teaching-learning that applies to all situations.

While selecting the appropriate approach and strategy we should see that it involves and motivates learners. It has to be convenient for working on it. It has to fulfill the objective of teaching-learning science and be workable.

Hence here is an overview of some of the approaches and strategies of teaching physical science.

Check Your Progress - 1

1. Explain the difference between an approach and a strategy

2.2.3.2. Constructivist Approach and 5E-Learning Model

a) Constructivist Approach

Constructivism is an approach to learning in which people actively construct or make their knowledge and that reality is determined by the experiences of the learner.

Constructivist teaching is based on constructivist learning theory. This theoretical framework holds that learning always builds upon the knowledge that a student already knows; this prior knowledge is called a schema. Because all learning is filtered through pre-existing schemata, constructivists suggest that learning is more effective when a student is actively engaged in the learning process rather than attempting to receive knowledge passively. A wide variety of methods claim to be based on constructivist learning theory.

Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information.

The constructivist teaching approach fosters critical thinking and creates active and motivated learners. It stresses that teachers create environments in which students can construct their understanding.

The constructivist approach has become the most valuable guiding principle for the teachers of science as well as for researchers in this field.

When a teacher enters the class, two questions arise – what to teach? And how to teach? The teacher is expected to be well equipped with the content knowledge as well as the pedagogy of physical science. Many constructivist pedagogies are available (Brooks and Brooks, 1993) Steffe and Gale, 1995; Larochelle, Bednarz and Garrison, 1998) which share certain common principles and indicate that eight factors are essential to constructivist pedagogy. They are.

- Learning should take place in an authentic and real-world environment;
- Learning should involve social negotiation and mediation;

- Content and skills should be understood within the framework of learners' prior knowledge;
- Content and skills should be made relevant to the learner;
- Students should be assessed formatively, serving to help them acquire further learning experiences;
- Students should be encouraged to become self-regulatory, self- mediated and self-aware of learning;
- A teacher should serve primarily as a facilitator of learning, not an instructor; and
- Teachers should provide for and encourage multiple perspectives and representations of content.

All constructivist teaching models are guided generally by five basic elements (Tolman and Hardy, 1995) which are:

1. Activating prior knowledge
2. Acquiring knowledge
3. Understanding knowledge
4. Using knowledge and
5. Reflecting on knowledge

NCF-2005 has strongly recommended the use of a constructivist approach to teaching-learning in schools. Black and Mc Clintock(1995) explains the Interpretation Construction (ICON) Model which consists of seven steps:

1. Observation
2. Interpretation
3. Contextualization
4. Cognitive apprenticeship
5. Collaboration
6. Multiple interpretations
7. Multiple manifestations

b) 5E Learning Model

The 5 E's is an instructional model based on the constructivist approach to learning, which says that learners build or construct new ideas on top of their old ideas.

In this constructivist model of learning, there are five stages of learning, and each stage begins with the letter E. The (five) 5Es are — Engage, Explore, Explain, Elaborate and Evaluate. In this model, conceptual change can be achieved by using five distinct, but interconnected phases. The 5 E's can be used with students of all ages, including adults.

Let us see it using the concept, **sound is produced by a vibrating body.**

i. Engage:

To engage students, teachers should connect the topic or concept at hand with prior understanding. Students are encouraged to ask questions or draw on experiences. The teacher does not correct any misconceptions about the topic or concept but does make notes about revisiting these misconceptions. The purpose of the engagement stage is to get students excited and ready to explore the topic or concept.

Students need to be engaged and focused on the learning tasks by asking questions, defining a problem and drawing their attention to an interesting event. This is the process of motivating to learn.

Example:

- The teacher exposes the students to various situations of production of sound by vibrating body and facilitate them to observe. She draws students' attention to the following situations
- Touching the front side of the neck when singing or making a sound
- Allowing them to strike a metal bowl, a bell, etc. and touching the object gently and recording their feelings.
- Watching carefully a video film on different musical instruments to know how these are played.
- Speaking his/her name loudly from the open end of a tin can, the other end of which is covered with a stretched balloon and few pieces of grains are kept over it and observing the movement of grains.

ii. Explore:

Once students are interested, they begin to investigate the problems associated with the topic or concept. Students pose real questions and develop hypotheses. The key concepts in the topic are identified while teachers provide hands-on activities. Students develop the skills that are needed to test their ideas. The teacher does not provide direct instruction at this time. Instead, the teacher leads students through inquiry-based questions as students work cooperatively in groups. During this stage, time is given to students to refine their hypotheses as they begin to reflect on the results of their investigations.

During the exploration phase, students actively explore the new concept through concrete learning experiences. They might be asked to go through the scientific method and communicate with their peers to make observations. This phase allows students to learn in a hands-on way.

Students get the opportunity to explore through hall senses. They are allowed to work together and build a base of common experience which assists them in the process of sharing and communicating. During exploration, the students' inquiry process drives the teaching-learning.

Example:

Students observe and gain some experience of how sound is produced in different situations. The teacher helps the students to explore what is common to all the above activities. Students observe that 'sound is produced in each case.' The teacher asks, "What is the second common thing you observe in all these situations?"They say,' It is vibration.' One of the students asks, "How sound is produced in a table by tapping it when no vibrations are noticed init?"

iii. Explain:

In this stage, students develop explanations for what they have already observed. They define the necessary vocabulary and connect their findings to prior knowledge. The teacher is expected to support student discussion and answer student questions. While this stage is a direct instruction phase, the discussions mean that this new information is shared collaboratively.

The teacher interacts with students to discover their ideas. The communication among the peers and with the facilitator may be observed to notice their questions, writing, drawing; and their performance of activities and experiments. This can help the teacher to facilitate progress in students' learning and integrating assessment with the teaching-learning process.

Example:

The teacher interacts with the students and helps them to explain why they cannot notice the vibration in a table. To give the students a concrete idea that mechanical energy can produce vibration, the teacher facilitates them to perform the following two activities:

- Take a tuning fork and beat it on a hard rubber pad. Do you hear a sound? Now bring the vibrating tuning fork and dip the tip of both the prongs in a glass of water and observe what happens.
- Bring the vibrating tuning fork near a table tennis ball suspended with a thread. What do you observe?

Tip of a vibrating tuning fork produces disturbances on water surface.

The teacher facilitates them to conclude that the prongs of the tuning fork are vibrating. In some cases, the amplitude of the sound is so small that we cannot see them. However, we can feel them.

iv) Elaborate

The elaboration phase of the 5E Model focuses on giving students space to apply what they've learned. This helps them to develop a deeper understanding. Teachers may ask students to create presentations or conduct additional investigations to reinforce new skills. This phase allows students to cement their knowledge before evaluation.

In this stage, students are allowed to expand the concept they have learned, make connections to other related concepts and apply their understanding to real-life situations. The teacher, who acts as the facilitator, helps the students to develop their understanding through additional hands-on work and minds-on activities.

Example:

Teacher encourages the students to suggest some more activities/ experiments/real situations where sound is produced and vibration can be felt. Students share their experien from their daily life about this concept.

v) Evaluate

In the final stage, students return to the engage phase to compare their earlier understanding of what they know now. They address any misconceptions they held, and the teacher makes sure these misconceptions are corrected. They reflect on what they know, and how they are now able to prove what they know in writing, discussion, and demonstration.

The 5E Model allows for both formal and informal assessment. During this phase, teachers can observe their students and see whether they have a complete grasp of the core concepts. It is also helpful to note whether students approach problems differently based on what they learned. Other helpful elements of the Evaluate phase include self-assessment, peer-assessment, writing assignments, and exams.

In this stage, the teacher sees if the students have attained an understanding of concepts and knowledge. During the teaching-learning process, the teacher adopts a continuous and comprehensive assessment of teaching-learning.
Example:

> Students' knowledge construction is tested through suitable questions and observation of their inquiry and process skills of science and participation in classroom activities. The teacher assesses each part of the activities involving students in formulating learning indicators and tasks specific to learning indicators. Teacher also facilitates peer assessment and self-assessment of students. Using a rubber band, a pencil box and two pencils, students perform an activity to observe that sound is produced by a vibrating body.

Check Your Progress - 2

Answer the following questions:

1. Write the uses of the constructivist approach.
2. What are the factors essential to constructivist pedagogy?

2.2.3.3. Problem Solving Approach, Concept Mapping Approach, Cognitive Conflict Approach, Inquiry Approach

Problem Solving Approach

"A problem arises when one has a goal but does not know how this goal is to be reached**. Karl Dunker.**

According to **Mayer** Problem solving is thinking that is directed toward the solving of a specific problem that involves both the formation of responses and the selection among possible responses".

Problem-solving takes place when a problem solver accepts to solve it as well as when his previous knowledge or patterns of behavior are insufficient or inappropriate to enable him to provide an acceptable solution. As such acquires new knowledge or capitalizes upon relationships that have not been seen before.

Problem-solving is the act of defining a **problem**; determining the cause of the **problem**; identifying, prioritizing, and selecting alternatives for a solution; and implementing a solution.

Learning experiences that allow independent thinking and multiple ways of approaching the problem encourage independence and creativity in learners. Problem Solving Approach is based on the idea of the involvement of students in real-life problems. It allows students to actively construct their learning by thinking, questioning, visualizing the situation, searching for a solution, doing activities and experiments and arriving at conclusion on their own.

Stages of Problem Solving

- **Problem survey** – analyzing a potential situation for items to be studied.
- **Problem description** – providing a clear statement of the problem to be studied.
- **Problem discussion** – making sure that the students understand what is involved in the problem.
- **Problem limitation** – isolating those parts of the problem that can be attacked profitably.
- **Planning for action** – preparing suitable hypotheses for investigation.
- **Further analysis and limitation** – tentative testing of hypotheses to identify those most likely to yield a solution.
- **Deciding the conclusion** – which hypothesis is the best solution to the problem.

Students should be made to write down as many as problems that persistently agitate their minds. The science teacher can also suggest add and redesign the entire list of problems for individual, small group and class investigations.

Activity:

Select a topic, say inertia. Do not tell the students what inertia is? Take a glass tumbler, five rupee coin and stiff card. Set the five rupee coin over the stiff card covering the empty glass tumbler. Give the card a sharp horizontal flick with a finger. If we do it fast then the card shoots away, allowing the coin to fall vertically into the glass tumbler. Ask students to answer why the coin fell inside the glass tumbler? Why not it shoots away? This is a problem. Students will come out with different hypotheses (tentative answers) like:

1. Glass tumbler has something to attract the coin
2. The card is lighter than the coin, hence it shoots away
3. The flick force push is sufficient to the card and not the coin.
4. Coin maintained its position through card changed
5. Then the student may try to do this experiment to test which hypotheses are right. After an experiment with using other coins that maintain the same thing. They will be helped by the teacher to read what inertia means? Students will understand the meaning of inertia.

This approach is used when the teacher wants to develop independent thinking in students. A problem is not if a child can solve it by his previous knowledge.

Concept Mapping Approach

Concept maps are graphical tools for organizing and representing knowledge about certain concepts. A concept map represents an understanding of the relationship and hierarchy between the important set of concepts. They promote meaningful learning in science.

Concept maps allow students to think deeply about science by helping them to better understand and organize what they learn and store and retrieve information more effectively. Figure 2 represents a concept map of an atom.

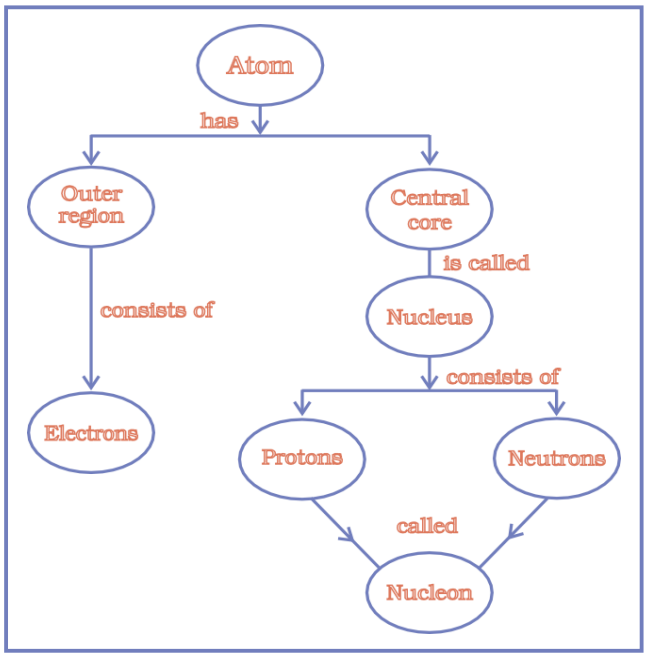


Figure 2 Concept mapping of an Atom

Concept maps benefit students as they are introduced to new science concepts; they embark on a cognitive process of constructing meaning and making sense by consciously or subconsciously integrating these new ideas with their existing knowledge. Concept maps provide a unique graphical view of how students organize, connect, and synthesize information. Concept maps allow students to (1) think about the connections between the science terms being learned, (2) organize their thoughts and visualize the relationships between key concepts in a systematic way, and (3) reflect on their understanding.

In sum, concept maps allow students to think deeply about science by helping them to better understand and organize what they learn, and to store and retrieve information more efficiently. Students also articulate and challenge their thoughts about science when they discuss their maps with each other. Concept mapping naturally integrates literacy and science by providing a starting point for writing about science.

Highly sophisticated maps show highly integrated knowledge structures, which are important because they facilitate cognitive activities such as problem-solving.

Concept mapping (as developed in its standard form by Novak in 1989) is considered to be an offset of the Asubelian approach (David P Ausubel propounded the theory of meaningful verbal learning) Novak himself asserts: my work and the work of my students on concept mapping has been based upon Ausubel's theory of meaningful learning (1963, 1968).

The following are the components of Concept Mapping

i. Concept – concept may be thought of as a mental framework of an event or an object
Example: A Cricket Ball is a concept because it has certain properties i.e. round, the surface is rough and it is used to play cricket. It has the label cricket ball.

A science concept is defined as regularity in events or objects designated by some labels example: speed, wave, mass work….. A concept could be a process (eg: focusing), a procedure (eg: calibration) or a product (potentiometer). Concepts are necessary for the thinking process in science. Figure 3 given below represents the Concept mapping of the concept "Energy".

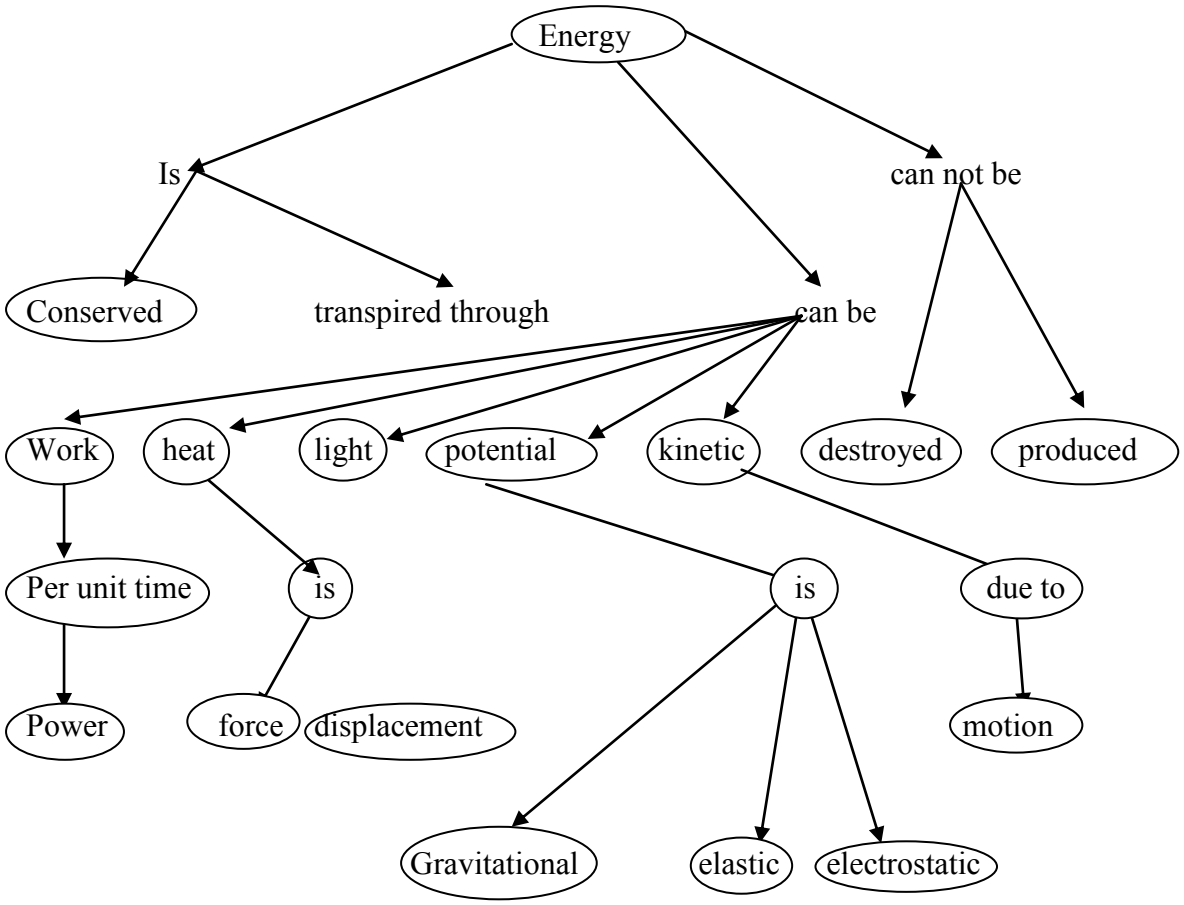


Figure 3 Concept mapping of the concept "Energy"

(**Source:** Novak and Gowin, Journal of Indian education Nov. 1999)

ii. Linkages: They are usually represented by an arrow on lines. They link two concepts appropriately

iii. Labels for Linkages: The label for most linkages is a word or a phrase. Labels highlight the relationship between the two concepts. These labels for linkages are also named as a proposition. There is no limit on the number of connecting lines.

How to Construct a Concept Map

Step 1: Select the key terms. Scan your curriculum unit and select the most important and critical terms related to the key concepts being taught. Using the terms you have selected, see if you can construct propositions that reflect what students should know and be able to express at the end of the unit. Keep the concept map manageable by selecting a shortlist of about 8 to 12 terms.

Step 2: Determine wherein the unit or curriculum the maps will be embedded. Concept maps fit best when alternated with the hands-on science activities in a unit.

Step 3: Create an activity. For maximum insight into student understanding, design the activity to follow the open-ended construct-a-map style, where students are only provided with the key terms.

Cognitive Conflict

A cognitive conflict strategy is a learning **strategy** that exposes students to a situation that is contrary to the concept and then the students are directed on experiments or demonstrations to prove the concept.

Cognitive conflict is the term educationalists use for the idea of **cognitive** dissonance and can be broadly defined as the mental discomfort produced when someone is confronted with new information that contradicts their prior beliefs and ideas. Constructivist models of learning tend to focus on the role of cognitive conflict in the successful challenging of misconceptions.

The cognitive conflict has been considered **important for learning** since the days of Piaget. He believed that when children's interactions with the world result in experiences that do not fit their current conceptions, their mental balance is disturbed (i.e., a **cognitive conflict** occurs).

Example:

A teacher in the class explained that water falling from greater height is used to generate hydroelectricity. Waterfalls on the rotating turbine kept in between magnetic fields help to generate hydroelectricity. A student in the class had a doubt how this water falling on the turbine be focused and watched by her. But when she visited the hydroelectricity generating station with her teacher she could observe that waterfalls through big pipes on the turbine down in the generating station. Human beings can reach there through a trolley. The rotating turbine in the magnetic field (as the water falls on it from height) leads to the production of hydroelectricity. Her earlier conception of hydroelectricity generation and new learning charges her cognitive concept, she doubts her cognitive structure. New her doubt/inadequacy of information is filled which made her resolve her cognitive conflict.

The learner generates her conception about how the natural world works. An inappropriate generalization can become very strong in the mind of the learner and then difficult to change. The personal conception is very much valid in the learner's framework and this can be her alternative conception (misconception or naïve concepts)

The occurrences of alternative conception which are significantly different from scientific concepts give rise to cognitive conflict. The cognitive conflict has a long tradition as a strategy for promoting conceptual change in science learning.

Conceptual Change

In the **conceptual change model**, students use their existing knowledge, which is their **conceptual** ecology, to determine whether the different conditions are met. The new conception must be intelligible (the meaning is understood), plausible (the concept is true), and fruitful (the concept is useful).

Conceptual change is the process whereby concepts and relationships between them change throughout a person's lifetime or throughout history. Research in four different fields – cognitive psychology, cognitive-developmental psychology, science education, and history and philosophy of science - has sought to understand this process.

Learning is visualized as a change in conceptions of a person rather than simply adding new knowledge to an already existing one. One of the models of conceptual change is given by Appleton (1997). This model is based on Piaget's theory and gives different possibilities of what happens when a learner is confronted with new experience/information. When new information is processed the following three possibilities may occur.

Identical Fit

The new information/concept/ experience may exactly fit the existing one (Schema). This means that the learner can make sense of new information based on existing knowledge that may not be scientifically correct.

Approximate Fit

The new information may form an approximate fit with an existing idea. These learners encounter new ideas, but cannot accommodate them. They cannot reach a situation where cognitive conflict can occur.

Incomplete Fit

The new information does not fit any of the existing ideas and cognitive conflict results. When the learner experiences an incomplete fit, she tries to resolve the conflict by seeking more information.

The main mechanism for change in Appleton's model of conceptual change is cognitive conflict.

Some Techniques to generate cognitive conflict are:

- Ask questions that create a dilemma.
- Help them to visualize the problem. A specific situation or a numerical problem can be set up.
- Demonstrate an activity. A brainstorming session or a group discussion can be arranged.
- Provide a computer-simulated situation. Allow the students to ask questions.
- Allow students to interact actively.

Inquiry Approach

Inquiry-based learning is an **approach** to learning that emphasizes the student's role in the learning process. Rather than the teacher telling students what they need to know, students are encouraged to explore the material, ask questions, and share ideas. It is a student-centered method of education focused on asking questions. Students are encouraged to ask questions that are meaningful to them, and which do not necessarily have easy answers; teachers are encouraged to avoid giving answers when this is possible, and in any case to avoid giving direct answers in favor of asking more questions. In this way, it is similar in some respects to the Socratic Method.

Benefits of Inquiry-Based Learning

- Reinforces Curriculum Content
- "Warms Up" the Brain for Learning
- Promotes a Deeper Understanding of Content
- Helps Make Learning Rewarding
- Builds Initiative and Self-Direction
- Works in Almost Any Classroom
- Offers Differentiated Instruction

An inquiry-based approach shifts the focus of science teaching and learning from an interest in the accumulation of facts and concepts to the processes that engage students in activity seeking answers to their questions or the questions raised by others. It emphasizes processes that scientists value for generating, validating and renovating knowledge. Students become involved in asking questions and seeking answers, their interest in the subject will also increase. Such an engagement in the process of science bolsters not only student's understanding of how science knowledge is constructed but also their development of scientific abilities and habits of mind.

The National Science Education standards have identified five essential features of an inquiry-based science class they are:

1. **Students are engaged by scientifically oriented questions:** These questions should be possible to investigate and aimed at probing the origins, causes, and processes related to objects, organisms, events and relationships in the natural world.

2. **Students give priority to evidence in responding to these questions:** Students obtain accurate evidence through repeated observations and careful measurements in natural settings or contrived settings. They also obtain evidence from secondary sources such as teachers, textbooks, other references and websites. All evidence is subjected to verification, questioning and further investigation.

3. **Students formulate explanations from evidence:** Explanations are based on logic and reasoning instead of personal belief, religious values, myths or superstition.

4. **Students evaluate their explanations in light of alternative explanations:** Students learn about other possible explanations through sharing with peers and reading related materials. This process should lead students to refine or reconsider their explanations based on available evidence.

5. **Students communicate and justify their explanations:** Students demonstrate the ability to articulate their questions and hypothesis describe investigative procedures and the experimental evidence, present plausible explanations and develop logical arguments based on an examination of existing scientific knowledge.

The following are the sample strategies for incorporating these features into a science classroom.

Teaching Activities:

- Provide opportunities for students to observe and explore their surroundings which should lead them to generate questions about the natural world.
- Have students read relevant texts and use the reading as a springboard to get students to raise and discuss relevant issues and questions.
- Guide students to reframe or reword their questions or wonderings into forms that can be investigated.
- Work with students to turn the purposes or objectives of traditional science activities into research questions.

Give priority to evidence:

- Give students opportunities to identify variables, develop procedures and devise strategies for collecting and presenting data.
- Engage students in data analysis through a search for patterns and themes.

Formulate explanations from evidence

- Encourage students to construct explanations based on experimental evidence.
- Discuss with students explanations based on personal belief and religious values may be interesting but not scientific.

Evaluate explanations

- Introduce information from the text and engage students in comparing and contrasting their explanations with those provided in the text or offered by their peers.

Communicate and justify proposal explanations

- Encourage students to talk with their peers about the inquiry.
- Provide opportunities for sharing through written and oral presentations.
- Involve students in debate.
- Allow students to challenge their explanations and those of their peers.

Check Your Progress - 3

Answer the following questions:

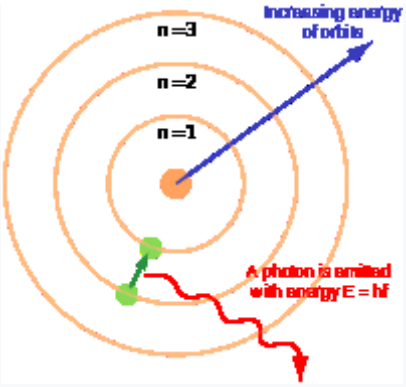
1. How does cognitive conflict occur?
2. Which are the possibilities that occur when the learner processes new information?
3. Explain the techniques to generate cognitive conflict.
4. Which are the 5Es in the constructivist learning model?
5. What is problem-solving according to Mayer?
6. Explain the stages of problem-solving.
7. Write the components of concept mapping.
8. Mention the steps of implementing a concept map activity in the classroom.
9. Construct a concept map for a topic of your choice.

2.2.3.4. Strategies of Teaching Physical Science: Analogy Strategy and Self Study Strategy

Analogy strategy

An analogy is a process of identifying similarities between two concepts. Learners can be introduced to a new concept by relating it with some familiar concept they already possess. It can help learners in the construction of their ideas. The familiar concept is *analogue* and the unfamiliar science concept is a *target*. Analogy strategy provides a bridge between analogue and target. Effective analogies motivate students, clarify students' thinking, help students overcome alternative conceptions, and facilitate them to visualize an abstract concept. An analogy will be effective if it is familiar to the students and its features and functions are congruent with those of the target. Its appropriate use can promote meaningful learning and conceptual development.

Analogy strategies involve comparing word parts to other known words. In a narrower sense, an analogy is an inference or an argument from one particular to another particular, as opposed to deduction, induction, and abduction, in which at least one of the premises, or the conclusion, in general rather than particular. The term analogy can also refer to the relation between the source and the target themselves, which is often (though not always) a similarity, as in the biological notion of analogy. The following diagram represents an example of Analogy.



Rutherford's model of the atom (modified by Niels Bohr) made an analogy between the atom and the solar system.

Teaching with Analogies (TWA) model includes the following six steps (Glynn, 1995):

1. Introduce the target concept;
2. Review the analogue concept;
3. Identify relevant features of the target and analogue;
4. Map similarities;
5. Indicate where the analogy breaks down; and
6. Draw conclusions.

Generally, analogies of a camera with the structure of the eye (target concept), a solar system with an atomic model(target concept), the electrostatic force with gravitational force, etc. are used in the teaching-learning process.

One can draw the following similarities between the solar system and the atom.

Analogue	Target
Solar System (familiar ideas) a. Sun b. Planets c. Sun and planets attract each other d. Sun has more mass than all planets.	Rutherford Model of Atom (scientific knowledge) a. Nucleus b. Electrons c. Nucleus and electrons attract each other d. The nucleus is very heavy as compared to electrons.

Thus, analogy strategy is mapping of relations between the analogue and the target. However, the use of analogue has its limitations and if the relationship is not established clearly and dissimilarities and unlikeness are not highlighted properly, it may lead to the formation of alternative conceptions instead of removing them. **Care should be taken that students remember the concept, not the analogue.**

Activity: Find the concepts of anyone chapter from the secondary school physical science textbook that can be taught through analogy

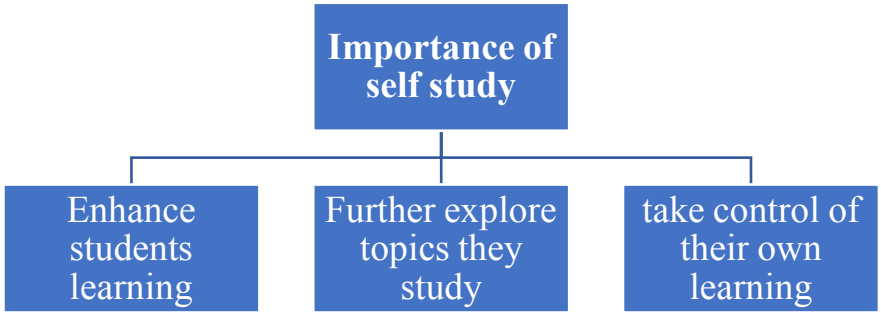
Self-Study Strategy

Self-study is the devotion of time and attention to gaining knowledge of an academic subject without assistance from a teacher or tutor. Self-studying is a great method students can use to enhance their learning experience, whether they are studying for a course or learning about a topic for fun. Using self-study, students can go beyond simply learning what their class textbooks and instructors teach them.

Self-studying is a learning strategy where students direct their studying – outside the classroom and without direct supervision. Since students can take control of what (and how) they are learning, self study can be a very valuable way for many students to learn.

Self-study and traditional classroom learning can be used together to help the student get the most out of his or her learning experience. Together these methods help students learn and retain information better, helping boost comprehension grades and motivation. Self-study is learner-centered and it facilitates them learning to learn and become an independent learners.

Importance of Self Study

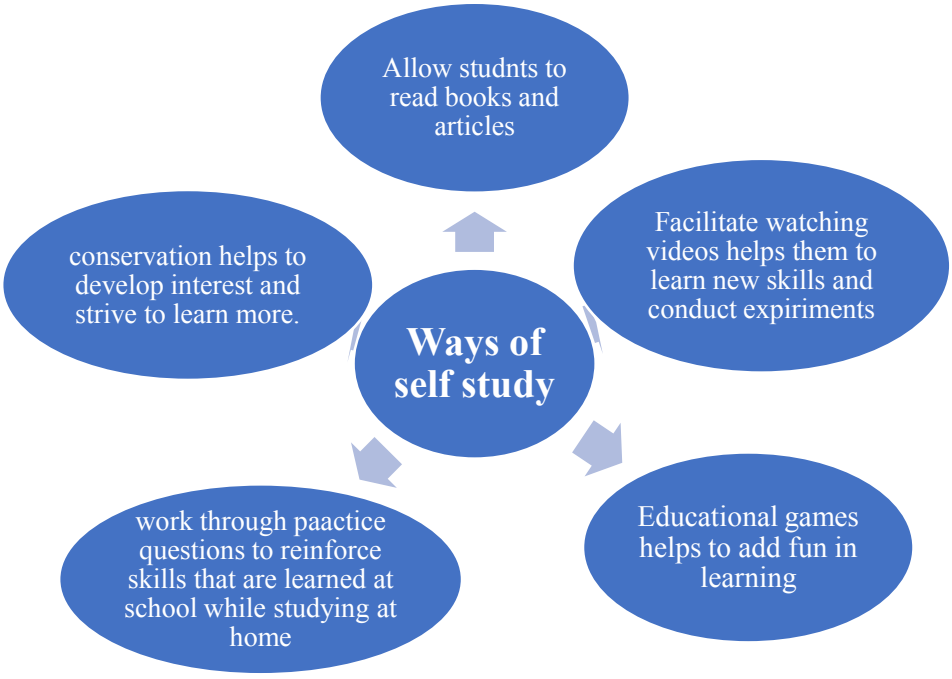


Benefits

- Students learn more effectively
- Students discover more about the topics they are studying
- It can boost a student's self-esteem.
- Students can learn at their own pace.
- Encourages curiosity

The benefits student can gain from self-study are endless and are determined by the teacher or student goals.

The best ways of self-study are,



- If the present textbook is analyzed carefully, there are application part of concepts which can be given as an assignment for self-study to students. Following steps may be followed to facilitate and monitor self-study.
- Identify the concepts or application of concepts that you find students can learn themselves.
- You may facilitate students to learn to draw concept maps/ flow charts/graphs / pictorial representation of the concept
- You may help them to select/choose the steps to be followed for the study. You may provide the name and page number of the reference book/textbook, list of relevant and reviewed websites for the concerned concept.
- Brief description of the activity/ experiment that needs to be performed
- Diagrams to be drawn.
- Time frame in which the activity is to be completed

Activity: Select a topic from a secondary school science textbook. Plan an activity for self-study by the students, examine/evaluate its success/fruitfulness.

Check Your Progress - 4

Answer the following questions:

1. What is the purpose of the inquiry approach?
2. Write five essential features of the Inquiry-based approach.
3. Why is analogy strategy important in science learning?
4. What is the importance of a self-study strategy?
5. How you as a teacher can help students to learn through self-study?

2.2.4 Let us Summarise

- Teaching-learning of science is a very complex process. This process involves learner, teacher, teaching, learning materials, suitable approaches and strategies and conducive learning environment leading to meaningful learning. The learner is the centre of the learning process and the teacher works as the facilitator of learning.
- An approach is used in the broader sense. It means a way of thinking and working in a set of discretion to accomplish certain goals. On the other hand, a strategy is a proper and systematic plan which aims to achieve the objectives.
- The constructivist approach fosters critical thinking and creates active and motivated learners. It stresses that teachers create environments in which students can construct their understanding.
- 8 essential factors of constructivist pedagogy are:

  Learning in an authentic and real-world environment;
  Learning involves social negotiation and mediation;
  Content and skills should be understood within the framework of the learner's prior knowledge ;
  Content and skills should be made relevant to the learner;
  Students should be assessed formatively, serving to help them acquire further learning experiences;
  Students should be encouraged to become self-regulatory, self-mediated and self-aware of learning;
  The teacher should serve primarily as a facilitator of learning, not an instructor; and
  Teachers should provide for and encourage multiple perspectives and representations of content.
- 5 E models have 5 stages: Engage, Explore, Explain, Elaborate and Evaluate.
- According to Mayer, problem-solving is thinking directed toward solving a specific problem that involves the formation of responses and the selection among the possible responses.
- Stages of problem-solving are:

  Problem survey – analyzing a potential situation for items to study.
  Problem description – providing a clear statement of the problem to study.
  Problem discussion – making sure that the students understand what is involved in the problem.
  A problem that can be attacked profitably.
  Planning for action – preparing suitable hypotheses for investigation.
  Further analysis and limitation – tentative testing of hypotheses to identify these most likely to yield a solution.
  Conclusion – Deciding which hypothesis is the best solution to the problem.
- Components of concept mapping are:

Concept – Concept may be thought of as a mental framework of an event or object. Any event or object is a concept because it has some identifiable properties or ideas associated with it.
Linkages – Usually represented by arrows or lines.
Labels for linkages: the label for most linkages is a word is or a phrase. Sometimes symbols are used such as +,-, x, / for linkages in mathematics.

- Steps of concept mapping are
  Steps 1 – Train students to write maps.
  Step 2 – Students create individual maps.
  Step 3 – Review the maps in small groups.
  Step 4 – Whole class discussion of certain parts of small group concept maps.
- The teacher can help students by providing the name and page number of the reference/textbook, a list of relevant and reviewed websites for the concerned topics, a brief description of the activity/experiment that needs to be performed, the diagram to be drawn and the time frame in which the activity is to be completed.
- When learning leads to the occurrence of alternative conceptions that are significantly different from scientific concepts give rise to cognitive conflict.
- Ask questions – Visualize the problem – Demonstrate an activity – provide computer-simulated situation allow students to interact actively.
- An inquiry-based approach shifts the focus of science teaching and learning from an interest in the accumulation of facts and concepts to the processes that engage students in actively seeking answers to their questions or questions raised by others.
- Students are engaged by scientifically oriented questions priority to evidence in responding to these questions.
  - formulate explanations from evidence.
  - evaluate their explanations in light of alternative explanations.
  - Communicate and justify their explanations.
- Analogy strategy provides a bridge between analogue (familiar concept) and target (an unfamiliar concept). Its appropriate use can promote meaningful learning and conceptual development.
- Self-study strategy is important because it enhances student's learning- help to further explore topics they study – helps students to take control of their learning.

2.2.5. Answer to 'Check Your Progress - 1, 2, 3 and 4'

Check Your Progress - 1

1. An approach is used in the broader sense. It means a way of thinking and working in a set of discretion to accomplish certain goals. On the other hand, a strategy is a proper and systematic plan which aims to achieve the objectives.

Check Your Progress - 2

1. The constructivist approach fosters critical thinking and creates active and motivated learners. It stresses that teachers create environments in which students can construct their understanding.
2. 8 essential factors of constructivist pedagogy are
   - Learning in an authentic and real-world environment;
   - Learning involves social negotiation and mediation;

- Content and skills should be understood within the framework of the learner's prior knowledge ;
- Content and skills should be made relevant to the learner;
- Students should be assessed formatively, serving to help them acquire further learning experiences;
- Students should be encouraged to become self-regulatory, self-mediated and self-aware of learning;
- The teacher should serve primarily as a facilitator of learning, not an instructor; and
- Teachers should provide for and encourage multiple perspectives and representations of content.

Check Your Progress - 3
Refer Section 2.2.3.3.

Check Your Progress-4
Refer Section 2.2.3.4.

2.2.6. Unit end Exercises

A. Write the answer in 3 to 4 pages:

1. What is a constructivist approach? Explain the 5E learning model with one example.
2. What is concept mapping? Explain its phases, write an example of concept mapping.
3. What is cognitive conflict? Explain the possibilities when new information is processed, write the techniques to generate cognitive conflict.
4. Write the meaning of the Inquiry approach. Explain strategies for incorporating essential features of inquiry in class.
5. What is a self-study strategy? How it benefits student learning? In what ways you can help students in this regard?

B. Write answer in about one page:

1. What is the difference between an approach and a strategy?
2. Write steps of a problem-solving approach.
3. How an analogy strategy is used in the science class?
4. Which are the factors essential for constructivist pedagogy?
5. What is problem-solving according to Mayer?
6. Write 2 examples of concept mapping from physical science.
7. What is the purpose of the Inquiry approach?
8. Specify the components of an effective teaching-learning process.
9. How you as teacher help students to learn through self-study?
10. Write five essential features of the Inquiry-based approach.

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 3 : Expository Approach

Unit Structure

2.3.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- understand the meaning and moves of the expository approach given by Henderson;
- identify the characteristics and sequence of expository approach;
- recognize the mode of using the expository approach;
- understand the difference between expository approach and discovery approach;
- learn the assertion made by Ausubel regarding the expository approach;
- recognise the examples of expository approach; and
- identify the advantages and limitations of the expository approach.

2.3.2. Introduction

Activity 1: Dear students, we may ask why to learn science? Why do we teach science? You may write 2 points for each of the above questions.

For sure you will write science is all around us. It is important to have an understanding of science for everyday life. Science has its values that are relevant to this modern world.

Children should be made to find the relevance of science in their daily lives. Many students may consider science too hard and monotonous to learn it right from the early stages of education. This can be one of the reasons that we observe a declining trend in the enrolment of students opting for science at higher levels. So, science teaching should be interesting and meaningful to the lives of the learner. Many times as a science teacher you must have thought what is the best method of teaching science and which strategies should be used to impart true science education?

Let us discuss the vision of true science education. There are three factors involved here-

- The learner (Child)
- The environment (physical, natural and social) around the learner and
- The object of learning (science)

In the context of NCF 2005, true to a child means that the teaching-learning of science should be understandable to the child and be able to engage the child in meaningful and

joyful learning. True to life means that science teaching – learning should convey significant aspects of science content at an appropriate level and engage the child in learning the process of acquiring and validating scientific knowledge.

Pedagogy of science deals with strategies of teaching-learning organising classroom experiences, knowledge about preconception so that they can assimilate and accommodate new information to make the learning of it.

As a teacher one has to teach facts, concepts and rules, generalisations across all the subject matter and at all levels of education.

In this unit 3 of block 2, we will study the expository approach as a teaching Approach.

2.3.3. Learning Points and Learning Activities

2.3.3.1. Expository Approach, Meaning and related aspects

Meaning of Expository Approach

Expository approach is also known as the transmission approach. In this approach, the teacher is communicating maximum information to the students in minimum 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 expository method, tell and do the method, deductive methods etc are included. The approach is totally teacher-centered.

In expository teaching, the teacher gives both the principles and problem solutions. In contrast to his role in discovery learning, the teacher presents the student with the entire content of what is to be learned in final form; the student is not required to make any independent discoveries. The usual verbal instruction of the lecture hall exemplifies expository teaching. It is sometimes called deductive teaching because the teacher often begins with a definition of concepts or principles, illustrates them, and unfolds their implications. Ausubel believes that the reason for the lack of research is that expository teaching has been identified with rote learning. The students, presumably, can only memorize the lectures by constant review and repetition. Indeed, it is possible to present a body of material so poorly that unless the students commit it to rote memory (as in the case of nonsense syllables), they have no way of remembering it. Expository teaching, however, can present a rich body of highly related facts, concepts, and principles which the students can learn and transfer. Textbooks are examples of expository teaching, and, as you very well know, they can vary in their methods of teaching subject matter and in their organization of that subject matter.

As in the case of discovery learning, it is probably difficult to find pure examples of expository teaching. In most classes, we find a combination of lectures (or teacher explanation) and discussions or lectures and laboratory and fieldwork. In these situations, although most of the instruction is under the direct guidance of the instructor, much of it is the most or less independent effort of the student.

Expository Method / Approach

If the initial move of the teacher is a statement of rule or generalization or principle (followed by clarification, justification and application of the rule) then the sequence moves are known as the expository method.

SR	**-**	**CR**	**-**	**JR**	**-**	**AR**
Statement of rule		Clarification of rule		Justification of rule		Application of the rule

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

The General Teaching Moves Identified by Henderson.

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.

They are:

Statement of Rule (SR): Statement of Rule under study may be made (assertion move) by either the students or the teacher.

Clarification of Rule (CR)

Through the use of examples, demonstrations, evidence of proof, discussions of sub-rule etc.

Justification of the Rule (JR)

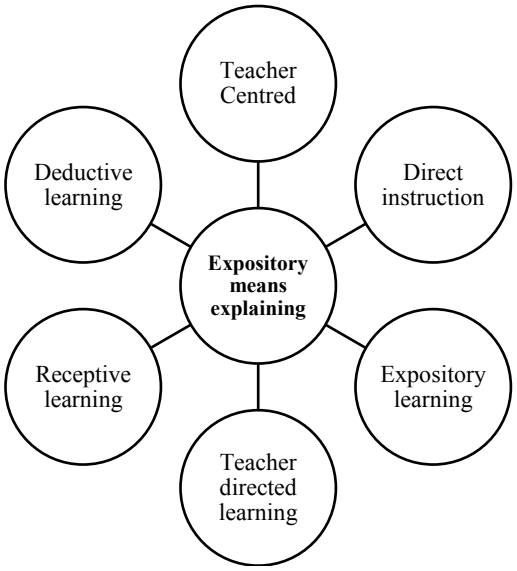
This move identifies the veracity (accuracy to facts) of that which is under study, cross proofs, opinions of experts etc.

Application of the Rule (AR)

To ensure that the students can 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 to above and changing the sequence of these moves. In short, all three moves are not mutually exclusive but are related to each other.

Characteristics of Expository Approach



Sequence of Expository Approach

The expository approach sequence is as follows:

Provides overview (academic organizer)

⇩

Provide instruction

⇩

Students glean insight obtain information from various sources

⇩

Provide experiences to reinforce/practice insight

⇩

Justification through several examples

⇩

Applying to daily life

Activity 2: By following the above sequence, plan your teaching for a topic your choice from VIII standard science. Discuss it with your fellow teacher.

Mode of using Expository Approach

The expository teaching strategy is direct instruction. A teacher is in the front of the room lecturing and students are taking notes. Students are being told (expository learning), what they need to know. However, expository instruction goes beyond just presenting students with facts. It involves presenting clear and concise information in a purposeful way that allows students to easily make connections from one concept to the next. The structure of an expository lesson helps students to stay focussed on the topic at hand. Often, when students are discovering information on their own, they can get distracted and conferred by

unnecessary information and have difficulty determining what is important. This is why expository instruction is one of the most common instructional strategies. Most educators believe students learn new concepts and ideas better if all the information they need to know is laid out before them.

Expository teaching is a strategy where the teacher presents students with the subject matter rules and provides examples that illustrate the rules. Examples include pictorial relationships, application of rules, content through historical information, and prerequisite information. Examples are given to give contextual elaboration and to help students see the subject matter from many different perspectives.

In expository teaching, the teacher gives both the principles and problem solutions. In contrast to his role in discovery learning, the teacher presents the student with the entire content of what is to be learned in final form; the student is not required to make any independent discoveries. The usual verbal instruction of the lecture hall exemplifies expository teaching. It is sometimes called deductive teaching because the teacher often begins with a definition of concepts or concepts or principles, illustrates them, and unfold their implications. Ausubel believes that the reason for the lack of research is that expository teaching has been identified with role learning.

In short, we can conclude that the teacher who uses expository teaching present information to their students in a purposeful way that allows students to easily make connections from one concept to the next. Students receive information from an expert, which could be the teacher or another expert, such as a textbook author or educational video. Whenever possible the teacher/instructor uses an advance organizer, which is a tool, used to introduce the lesson and illustrate the relationships between what the students about to learn and information they have already learned. The structure of an expository lesson is designed to help students stay focused on the topic at hand.

Difference Between Expository Approach and Discovery Approach

Expository teaching is more popular because it is more efficient and takes less time than discovery learning. When combined with practice, it is very successful in teaching concepts and principles. Expository teaching offers to students the best opportunity to obtain an organized view of the discipline he is studying because the teacher can organize the field much more effectively for learning than novice student can. In discovery learning the concern to teach the techniques of discovery overrides the concern for learning the unifying principles of a discipline.

Check Your Progress- 1

Mark ✓ or X for the statements given below:

1. The expository approach is also called the discovery approach
2. The main proponent of the expository approach is David Ausubel
3. The sequence move of the expository method is SR-CR-JR-AR.
4. Expository means ‘explaining’
5. One of the characteristics of the expository approach is student active involvement in learning by doing.

Fill up the blanks with appropriate word/ words

1. Expository approach is basically _____ teaching
2. In expository approach teacher gives both principles _____ and _____

3. In expository approach teacher uses _____ to introduce the lesson
4. Expository learning is more efficient and takes _____time than discovery learning

2.3.3.2. Assertion made by Ausubel regarding Expository Approach

Ausubel provides a clear picture of the merits. The art and science of presenting ideas and information meaningfully and effectively so that clear stable and unambiguous meanings emerge and are retained over a long period as an organized body of knowledge - is the principle function of the pedagogy. This is a demanding and creative rather than a routine and mechanical task. The job of selecting, organizing, presenting and translating subject matter content in a developmentally appropriate manner requires more than role destiny of facts. If it is done it is work of master teacher and is hardly a task to be disdained (refused). . . . . ."

Activity 3: Select a topic from the science textbook of IX Standard. Plan the teaching-learning steps through expository as well as discovery approaches. Find how both are different from the teaching point of view.

Examples of Expository Approach

Let us study the following example wherein the expository method has been applied to a physics topic from IX standard science.

Statement of Rule (SR):

If a body of a certain mass m is raised to the height h from the ground and when the object is in a state of strain it is said to possess potential energy. It is represented by P.E=mgh g=9.8m/sc2. Potential energy can be defined as energy due to height /strain in the object.

The teacher can make use of different media to show this rule to the students such as writing on the board regarding the representation of Potential energy or use a PPT Slide or preparing charts representing potential energy.

After defining potential energy, the teacher will give many examples by the demonstration of Potential energy. The teacher points out the presence of Potential energy in all the examples.

Clarification of Rule (CR)

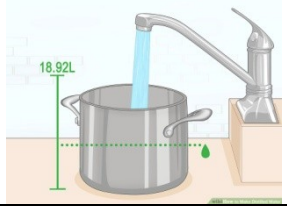
To clarify the definition of potential energy is due to height/strain, the teacher provides specific examples.

Materials Required for Activities:

Marble, sponge, filled with water container having a tap, chart of waterfalls, spring, axe blade, pole vault

Recording Observations After doing Demonstration of Activities

Sl. No.	Objects	Activity	Observation
1.	Marble and Sponge	Letting marbles to fall on the sponge from different heights.	Impression increased as the height from which marble is left to fall.
2.	Chart of waterfall	Water falling from a height	It has potential energy

3.	A container filled with water and having a tap 	When water is falling it has potential energy. If we keep our fingers we experience potential energy.	Falling water has potential energy.
4.	Long axe blade	The blade is bent on one side and an object is kept in front of it.	The bent blade moves the object as it has potential energy due to strain in it.
5.	Spring	Spring is compressed and an object is kept in front of it.	It pushes the object forward as it possesses potential energy due to strain in it.
6.	Picture of pole vaults same	The sportsperson playing pole vault (a long wooden stick)	Woolen stick pushes the player to the other side of the net as it possesses potential energy.

The teacher must give some more examples to clarify the presence of potential energy in a body. Each example should be related to the definition of potential energy. This helps the students to assimilate the definition properly.

Justification of the Rule (JR)

Here, the teacher has to justify his/her explanations given to define the potential energy of the body. Students can be asked to perform these activities / done by the teacher) and record/check observations of the teacher.

Application of the Rule (AR):

The teacher can show how the understanding of the potential energy is made use of in our life.

The teacher used a chart of a waterfall to show that falling water has potential energy. This can be linked to other waterfalls also container having tap from which waterfalls has potential energy. It can be linked to an overhead tank at our house. The teacher used an axe blade spring and show that strain in the objects results in potential energy. This can be shown by bending our finder and with it Pushing a marble. Potential energy is used to generate hydroelectricity.

Every time teacher relates the explanation to definition mode, it is called Advance organizer as made by Ausubel. All the above explanations related to the definition in the beginning that is the rule.

Example: 2

We have gone through an example from physics where the expository approach is applied. Now, we can study how this method in topic chemical combination/approach is used for teaching-learning a topic from chemistry.

Statement of rule:

When two or more elements combine together to form a new substance or substance the change is called a chemical change. One of the types is a chemical combination. A reaction in which two or more substances combine to form a single compound is called a chemical combination.

The teacher can make use of different media to show this rule (definition) to the students such as writing on the blackboard regarding the representation of Chemical change or use PPT slides or writing examples of chemical combination.

After defining the writing chemical combination the teacher will give many examples of chemical combination by using PPT slides. A teacher writes chemical equations to show chemical combinations.

Clarification of the Rule

To clarify the meaning of chemical combination teacher gives specific examples

Sl. No	Chemicals used	Activity	Observation	
1.	Hydrogen and oxygen	Combining both $2H_2+O_2$	Water	$2H_2O$
2.	Magnesium and Oxygen	Combining both $2mg+0_2->2mgo$	Magnesium oxide	
3.	Sodium and Chlorine	Combining both $2Na+cl_2$	Sodium chloride	2Nacl
4.	Calcium oxide and carbon dioxide	Combining both $Cao+CO_2$	Calcium oxide and carbon dioxide	$CaCO_3$
5.	Iron and oxygen	Combining both $4Fe+3O_3$	Ferric Oxide	$2Fe_2O_3$

The teacher may give some more examples to clarify the chemical combination of substances. Each example must be related to the definition of chemical combination. This helps students to assimilate the meaning of chemical combination.

Justification of the Rule

A teacher has to justify her/his explanations regarding chemical combination. Students may be asked to perform certain activities under the direction of a teacher with needed precautions. The observations can be checked by students by referring to books and websites.

Application of the Rule

Teachers can show how these chemical combinations have helped us. Hydrogen and oxygen naturally combine in nature to form water which is essential for all of us to lead our life. Sodium and chloride are poisonous whereas when combined to form sodium chloride which is very useful and exists in nature especially in sea water. Calcium carbonate is used as

an antacid and colouring agent. Magnesium oxide is used in crackers. Ferric oxide is used in the pharmaceutical industry and the cosmetic industry as a colouring agent.

Every time teacher focuses her explanation on the definition made. It is called an advance organizer as explained by Ausubel. All the explanations of chemicals are related to the definition of chemical combination. Thus the expository method is a useful method/approach.

Activity 4: Suppose you are required to teach conductors and insulators to your students through an expository approach. Plan the steps.

Advantages and Limitations of Expository Approach

Advantages

This is the most preferred method/approach by the teacher all over the world. This method has definite advantages. These are given below:

- **Exploratory** learning encourages learners to examine and investigate new material to discover relationships between existing background knowledge and unfamiliar content and concepts.
- Effective in communicating new knowledge in a short 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 present to the students resulting in 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.

Disadvantages

Although this is a widely used approach/method, it suffers from the following disadvantages

- Students are passive to a large extent. All the cues provided by the teacher.
- Role memorization is encouraged
- Not effective for a higher level of objectives especially analysis, evaluation and creativity.
- Students depend on the teacher all the time.
- No scope for the creativity of the students.
- Not at all suitable at a lower level.

Check Your Progress - 2

1. **Answer the following question:**
2. What is the assertion made by David Ansubel regarding expository teaching?
3. What are the advantages of the expository approach?
4. What are the disadvantages of the expository approach?

2.3.4. Let us Summarise

- The expository approach is known as the Transmission approach which helps teachers communicate maximum information to the students in less time.
- The main proponent of this method is David Ansubel.

- In this there approach various methods such as the expository method, tell and do the method, deductive method etc are included.
- The sequence move of the expository method is SR-CR-JR-AR.
- In expository teaching, the teacher gives both the principles and problem solutions. The teacher presents information to the students in a purposeful way that allows students to easily make connections from one concept to the next.
- The structure of an expository lesson is designed to help students to stay focused on the topic at hand.
- An advanced organizer is a tool used to introduce the lesson and illustrate the relationships between what the students are about to learn and the information they have already learned.
- In discovery learning the concern to teach the techniques of discovery overrides the concern for learning the unifying principles of the discipline.
- Advantages are: effective in communicating new knowledge in a short period, gestaltic views of the subject and effective for knowledge and comprehension objectives and suitable for all types of subject matter and high levels.
- Disadvantages are: students are passive, role memorization not effective for higher-level objectives and no scope for student creativity.

2.3.5. Answer to 'Check Your Progress - 1 and 2 and'

Check Your Progress - 1
Mark ✓ or X for the statements given below:
a) X b) ✓ c) X d) ✓ e) X

Fill up the blanks with appropriate word/ words
a) direct, b) problems and solution, c) advance organizer, d) less

Check Your Progress - 2

Answer the following questions
1. The art and science of presenting ideas and information meaningfully and effectively so that clear, stable and unambiguous meanings emerge and are retained over a long period as an organized body of knowledge is the principle function of the pedagogy.
2. Advantages are effective in communicating new knowledge in a short period, gestaltic view of the subject, and effective for knowledge and comprehension objectives and suitable for all types of subject matter and high levels.
3. Disadvantages are students are passive, role memorization not effective for higher-level objectives, no scope for creative expression and not suitable for lower classes.

2.3.6. Unit end Exercises
A. Answer the following questions in about 3 pages each:
1. What is the expository approach? Explain its sequence moves with examples.
2. Explain general sequence moves of expository approach identified by Henderson
3. Explain the "tell and do method" as an expository approach with an example.
4. What are the advantages and limitations of the expository approach?

B. Answer the following in a page each:
1. What is the expository approach?
2. How the expository approach is different from the discovery approach

3. Write the sequence of expository approach
4. Specify the advantages and disadvantages of the expository approach.
5. Why do teachers prefer to use the expository approach to other approaches?
6. Briefly explain the characteristics of the expository approach.

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 4 : Investigatory Approach

Unit Structure

2.4.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- recognize the meaning and steps of investigatory approach;
- understand the method of designing an investigatory project;
- identify the meaning and importance of framing the hypothesis.
- recognize the meaning of variables in the investigatory approach;
- identify the control and experimental groups;
- understand the significance of establishing the reliability of the test;
- recognize the procedure of conducting an investigation;
- understand the method of interpreting data;
- identify the methods of application of reporting investigation;
- give examples for investigatory approach;
- list advantages and disadvantages of investigatory approach;
- recognize the hints for investigation in different science subjects;

2.4.2. Introduction

In this unit let us learn an important approach called the Investigatory approach/method used in the Teaching-learning of Science. A scientific investigation is a holistic approach to learning science through practical work (Woolnough 1991) "The aim of science investigation is to provide students opportunities to use concepts and cognitive processes and skills to solve problems" (GOH and Duggan 1996, P.26).

Investigatory Method is a method of learning and teaching that gives students opportunities to direct their learning as they explore the science underlying realistically complex situations. This approach

- provides a lot of opportunities for the student to participate in classroom activity
- allows investigating a problem using Scientific Method
- Focuses greatly on Investigation and enables learner's active involvement
- De-emphasizes the teacher's authoritative role in the classroom

Let us learn more about the Investigatory approach in this Unit.

2.4.3. Learning Points and Learning Activities

2.4.3.1. Meaning, Need and Phases of Investigatory Approach

Millar (2010) has defined investigation as practical activity in which students are not given a complete set of instructions to follow (a recipe), but have some freedom to choose the procedures to follow and to decide how to record, analyze report the data collected. They may also (though this will not be taken as defining characteristics) have some freedom to choose the question to be addressed and/or the find conclusion to be drawn like "experiments" "investigations" are a subset of "practical work".

Students gain most from science investigation when they "discuss expectations, observations, conclusions, theories and explanations before, during and after conducting the activity" (Patrick & Yoon 2004 P319). Miller (2004) agrees with the importance of discussion before and after the investigation.

Investigative proves includes four phases – a design and planning phase, a performance phase, a reflection phase and a recording and reporting phase (Hodson 2009). Focussing on using science investigation to develop conceptual understanding, carry out a complete investigation of this kind enables students not just to do but learn science concepts and understanding the nature of science (Hodson 1990, 2009). Students need the understanding, carrying out a complete understanding of science concepts (substantive knowledge) and skills (understanding of science procedures) to successfully carry out a science investigation (Abrahams and Miller 2008, Roberts & GOH 2003)

Need to use Investigatory Approach

The philosophical and psychological advantages appear to be many. These methods/approaches increase intellectual potency: cause a shift from extrinsic to intrinsic rewards; help student learn how to investigate; increase memory retention; make instruction student-centered, thereby contributing to a person's self-concept; increase expiatory levels; develop multiple not just academic talents; avoid learning only on the verbal level, and allow more time for students to assimilate and accumulate information. There is much evidence that students taught by these methods perform significantly better on cognitive tasks involving critical thinking than those taught by traditional instruction. The retention and critical thinking ability of students in investigative oriented classes, however, is greater.

The Swiss psychologist, Jean Piaget indicated that adolescents are in the process of developing formal thought and should, therefore, have opportunities to use higher-level thinking, hypothetical deductive and reflective thinking are two characteristics of this stage of development. Formulating hypotheses, designing investigations, evaluating data, and looking over an investigation to determine how it can be improved all these require mental operations. The general term investigative is used to include both discovery and Inquiry teaching approaches.

The Swiss psychologist, Jean Piaget, has written "The teacher creates situations through which children discover structure". The structure is inherent in the experiments themselves. The generalization is made by the child (student) as he/she discovers the likeness, the difference and the cause and effect involved in performing each experiment.

Quick success reinforces the child's desire to learn. The concepts build, one upon another, resulting in an orderly meaningful structure.

Phases in the Designing of Investigation

The following are the phases in the design phase of the Investigatory Approach.

A. Forming a Question

Any investigation begins with a question. The best question for a student investigation is one which the student has thought of himself. It may arise from something he has learned in class, or it may simply be something that has occurred to him from observing his daily surroundings. Students will be interested in it. When a student comes to you(teacher)with his question, you should offer him curious books and other sources where he can find information relating to his problem. It may be that he will be able to find the answer in a book and there will be no opportunity for an investigative project. But, if he reads the information available to him and still cannot find the answer or if the answer given to him in a book or scientific journal does not satisfy him completely, he has the beginning of an investigation, a question to which no suitable answer is available.

B. Utilising Sources of Information

Students may also consult competent people living in their area such as scientists, college lectures, science or medical technicians, doctor's nurses, who may know the subject in which he is interested.

The teacher should guide & counsel the student as it is his responsibility to complete the investigation.

C. Forming Working Hypotheses

From the facts available to the student from his reading and observations, he should now try to form a hypothesis or hypotheses, a tentative solution to the problem. The hypotheses and the prediction resulting from them are then usually put in the form of an if-then ..... statement.

Let us suppose that an investigator's problem concerned the rate of fall of various free-falling objects. Then the formal statement of his hypothesis and perdition might read: If the prediction weight of a free-falling object determines its rate of fall then the greater the weight of the object the greater will be its rate of fall. It is called the working hypothesis for it contains the scientist's explanation of the phenomenon and a logical prediction based on the explanation. Once the formal statement of the working hypothesis has been agreed upon the student will have to devise an experiment to test his hypothesis. Here again, teacher guidance will be valuable. By putting questions to the student, he can bring to his attention to possible sources of error.

D. Designing an Experiment

The design of the experiment is the student's plan of attack. He should plan each stage of the experiment step by step so that he has a clear idea of how he will proceed to solve his problem. He should take into consideration possible sources of error and design his experiment so that these errors will be eliminated. This is the proper function of experimental design, eliminating error before it has a chance to occur. Here clear thinking and attention to detail are especially important for the investigator, for an oversight could easily make the results of the experiment invalid.

E. Variables

A variable is any factor that may affect the results of the test. The Independent variable is the factor that is responsible for the effects of the results of the test. The Independent variable is the factor that is responsible for the effects. For example, in our falling bodies, investigation weight is the independent variable because the investigator believes that it is the difference in the weights of objects that causes the difference in their rate of fall.

One fact was understood by the investigator which had not concerned him until now the rate of fall (speed) is equal to distance/ time. The investigator reasoned that when distances are equal and times are not, then speeds cannot be equal. Therefore, he reasoned, the rate of fall can be measured by noting the time it takes for an object to fall from a known height. Time then becomes a dependent variable. If the hypothesis is correct, the dependent variable (time) is dependent upon the independent variable (weight).

F. Direct Controls

To do this, the student must control all variables except the independent and dependent variables. That is, all other variables must be kept constant during the experiment for example, in devising a proper test of his hypothesis; our investigator would have to drop various objects from the same height and record the amount of time it took for them to fall. These objects should differ in no significant way but for weight. He must use objects of the same shape, volume and so forth. He would then be exercising control over the variables.

G. Control and Experimental Groups

Control groups are those groups in which the independent variable does not play a part. In this experiment, there are two control groups and there is one experimental group; that is a group of large lead balls in which the independent variable is thought to play a part in determining falling speed.

The importance of a control group will be realized when the student begins to interpret the data, for the control group allows the investigator to say definitely whether or not the independent variable affects the dependent variable. If there is no difference between the performances of the combing groups and the experimental group, then the investigator must conclude that his hypothesis (Weight determines falling speed) is not correct for the independent variable is seen to not affect the phenomenon he is examining. If, however, there is a recognizable difference between the performances of the control groups and the experimental groups the investigator can reasonably say that his hypothesis is correct.

H. Reliability of the test

When your student is convinced that the design for his experiment is valid, he must face the second criterion for experimental design – reliability of the test. He must give proof of the experiment's reliability by showing that it can be identically performed on repeated occasions with equivalent results.

For example, in our falling bodies experiment the investigator cannot be content with simply recording the times which it takes for three balls (One small, one large and one the same size as the large one and as light as the small one) to fall from a given distance.

The results of any one trial might be due to some random error or chance. Therefore, the student must perform several trials so that he can show conclusively that the same results

will be obtained every time the experiment is performed. For the falling bodies experiment, the investigator must have an assortment of large and small lead balls and a control group of large porcelain balls, each equal in weight to one of the small lead balls but of the same size as his large lead balls. The times for these balls to fall from a given height can be then be measured and compared through a series of trials and the investigator will have conclusive proof that his results are accurate and consistent. His experiment will yield the same results for other investigators using the same techniques and the same apparatus.

I. Adequacy of the Instruments

The third criterion for proper experimental design is the adequacy of the instruments for the measurement of the variables is reasonably accurate and consistent.

Check Your Progress - 1

1. Why is it important to use the investigatory approach in teaching science?
2. Which are the phases of designing an investigatory approach?
3. Why do you frame the working hypothesis?
4. What are the control and experimental group in the investigation?
5. What is the reliability of the test?

2.4.3.2. Conducting and Reporting Investigation

Conducting Investigation

In Conducting Investigation, the student should now prepare a work schedule allowing him a specific amount of time for each remaining step of the investigation.

For instance, one student may allow two weeks for the construction of the apparatus, two weeks for experimenting and two weeks for interpreting the data. An extra week allotted to overcome any unforeseen difficulties would mean that the entire investigation should be completed within seven weeks. The following are the steps in conducting the Investigation.

a. Constructing the Apparatus:

When the student is constructing the apparatus you may aid him with suggestions, which will make the work easier for him, but he should do his work. This will build up his confidence in himself and he will learn to be independent. The accuracy of his measurements will depend upon the precision of his apparatus; he cannot be satisfied with poor quality work.

b. Conducting the Experiment:

This stage of the investigation should cause him no difficulties if he has learned proper scientific techniques during practicals and demonstrations. He will know that he must be consistent in his methods and logical in his thinking.

c. Objective observations:

You must teach the student the value of making accurate observations. He must record things exactly as they happen. A student may allow his hypothesis to influence his observations that is, he records what he thinks should be taking place instead of what is occurring.

During the experiment, many new questions may occur to the student due to his observations. He should keep a record of these questions, but he should not let them

divert him from his goal of finding an answer to his original question. These new questions may be taken up later as the basis for further investigations.

d. Keeping Records:

You must impress upon your student the necessity for keeping a complete record of his experiment. This will be essential when the time comes for him to interpret his data and write a report of the investigation. Before beginning the experiment, the student should prepare a form on which the observations are recorded. This form will usually include a list of all variables; the condition of each variable should be recorded at each trial.

e. Interpreting the Data:

The final task of the student is the interpretation of his data. In the course of the experiment, the student will probably have accumulated a large amount of data. This is no more than a task of clear, logical, objective thinking. In the course of the experiment, the student will probably have accumulated a large amount of data. He must arrange this methodically and summarise the results from which he will judge whether to accept, modify, or reject his hypothesis. If both hypothesis and experimental design are correct, the dependent variable will be found to change as the independent variable changes. If the results of the experiment do not show this to be true, then either the hypothesis or the experimental design is incorrect.

f. Helping Student Interpret the Data:

Since interpreting data is largely a matter of clear thinking, the student should draw his conclusions. The help you give can be in the form of a question such as: what do these figures prove? Why? Are there any other possible explanations for the results? Have you taken into consideration all your data s? In this way, the student may learn to think for him, to have sound reasons for his conclusions and to stand by his decisions.

Activity 2: Select a problem for VIII student science and plan the design of the investigation by following the explanation given above.

Reporting Investigation

To explain the entire report comprehensively, he (student) should write a report which will describe clearly, precisely and accurately every step which he has taken. The student will probably require little encouragement to write such a report for he should be proud and eager to gain recognition for the work he has done.

Outline of Typical Report:

I. Introduction:

A. History: This section is intended to make the reader familiar with the background of the problem which the student has investigated.
B. Hypothesis: At the end of the introduction, the student should state his hypothesis.

II. Experiment:

A. Subjects: If human subjects are used for the investigation, relevant subject variables such as age, sex, height, weight or any others should be described.

B. Apparatus: This section should contain a concise but detailed description of the apparatus used in the experiment.
C. Procedure: The student must give a description of the controls and variables used and explain the procedures for the control and experimental groups.

III. Result:

In this section, the student simply presents his results. This is usually done in the form of graphs and tables.

IV. Discussion:

It consists of the student's interpretation of his data and his conclusions. It may indicate the limitations of the experiment.

V. Summary:

This should be concise and precise and it gives the reader a brief overview of the entire work.

Example of Investigation

Effect of exercise on metabolism

An experiment was conducted to observe the effect of vigorous exercise on the metabolic rate of 24 male and 24 female students ranging from age 14 to 16 years old. The subjects were divided according to diet and sex and their data was tabulated separately. It was found that under conditions of exercise more CO_2 was produced than under the control rest condition likewise, it was found that males have a higher metabolic rate than females and that there are no differences due to vegetarian and non-vegetarian diet.

It was suggested that the exercise and subject variables be more clearly delineated and that the indicators of metabolic rate(perspiration, increased breathing rate, CO_2produced and body heat) be examined independently of the exercise condition.

Check Your Progress - 2

1. Arrange the steps for conducting the investigation in an order
    a. Conducting an experiment
    b. Constructing apparatus
    c. Interpreting data
    d. Objective observation
    e. Keeping records

2. Specify the meaning of objective observation and interpreting data in an investigation.
3. Why do we keep records of investigation?

2.4.3.3. Advantages and disadvantages of Investigatory Approaches

Advantages

- A good approach to learn science.
- It promotes intellectual potency of learner
- It promotes intrinsic motivation

- It promotes the self-concept of the learner
- It increases memory and retention of learner
- It promotes the development of the multi-talents of learners.

Disadvantages

- All cannot be investigators.
- It needs a lot of planning.
- Experimentation in the absence of teacher guidance may be less fruitful.
- All topics cannot be learnt by the investigation.
- It is a time-consuming approach.

Hints for Investigation

Hints for Investigation in Chemistry

- Will all Chemicals dissolve in the same amounts of water at a given temperature?
- Can you determine the temperature at which different chemicals in the solution will crystallize?
- How can rusting of Iron be prevented? could you coat nails with different materials to prevent the oxygen from reaching the iron? Will rust occur without moisture?

Hints for Investigation in Physics

- Will magnets attract things through paper? Through tin? What materials will magnetism pass through? What metals will magnets attract?
- Does the paper contain electricity? Rub sheet of newspaper with a ruler while holding the sheet of newspaper against a smooth surface. How do you know electricity affects the paper?
- What causes static electricity? Try rubbing wool, silk, nylon, cotton and rubber with a glass rod Do these materials become charged?

Hints for Investigation in Biology

- What is the effect of carbon dioxide on plant growth? Will plants live in an atmosphere of pure carbon dioxide? In an atmosphere of no carbon dioxide?
- What is the effect of oxygen on plant growth? Can a plant live in pure oxygen? In the air lacking oxygen?
- In which colour of light do plants grow the best? Cover a few leaves with other colours and test for starch formation.

Check Your Progress - 3

Enumerate the hints for investigation in Physical Science

2.4.4. Let us Summarise

- The investigative approach has many advantages. It increases intellectual potency; cause a shift from extrinsic to intrinsic rewards; help student learn how to investigate; increase memory retention; make instruction student cantered, thereby contributing to a person's self-concept; increase expectancy levels; develop multiple not just academic talents; avoid learning only on the verbal level; and allow more time for students to assimilate and accumulate information.

- The general term investigative is used to include both the discovery and Inquiry approach.
- The Swiss psychologist Jean Piaget indicated that adolescents are in the process of developing formal thought should therefore having opportunities to use higher-level thinking.
- Formulating hypotheses, designing investigations, evaluating data and looking over an investigation to determine how it can be improved all require these mental operations.
- Steps of investigative approach are design, method of investigation and reporting.
- Designing includes forming a question, utilizing sources of information, forming working hypotheses, designing our experiment, planning variables, direct controls, control and experimental groups, reliability of test and adequacy of the instruments.
- Conduction of the experiment involves constructing the apparatus, conducting the experiment, observations, keeping records & interpreting data.
- Reporting of investigation involves an introduction, experiment; results, discussion and summary.

2.4.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1. It is a holistic approach. Gives opportunities to use concept and cognitive processes and skills and discuss expectations, observations, conclusions, theories and explanations before, during and after conducting the investigations.
2. The steps of designing an investigation are; forming a question, Utilising sources of information, forming working hypotheses, designing an experiment, variables, direct controls, control and experimental groups, reliability of the test and adequacy of the instruments.
3. Working hypothesis is the tentative solution based on information accumulated. It contains the scientific explanation of the phenomenon and a logical prediction based on the explanation.
4. A Control group is that group in which the independent variable does not play a part. The experimental group is one where the independent variable has its role/effects.
5. The reliability of the experiment is by showing that it can be identically performed on repeated occasions with equivalent results.

Check Your Progress - 2

1. Steps of conducting the investigation
   b, a, d, e, and c
2. Objective observation refers to accurate observation. An expression has to observe the things as it is and record it. A lot of information/data collected has to be interpreted properly and justified. This shows the authentication of the experiment.
3. While doing an investigation, many minute details are collected that must be used in all the steps of the investigation. Hence, keeping a record of all those steps followed is to be considered and recorded immediately to give a complete picture of the investigation.

Check Your Progress - 3

1. Refer Section 2.4.3.3.

2.4.6. Unit end Exercises

Answer the following in about 3 pages

1. What is the meaning of an investigation? Explain its steps.
2. Describe the steps of investigation with an example.
3. What is the hypothesis? How do you frame a working hypothesis?
4. With an example frame independent and dependent variables.
5. Specify experimental and controlled groups in an investigation.
6. Explain briefly the design of an investigation?
7. Specify the procedure of conducting an investigation?
8. What is establishing the reliability of a test?
9. How do you interpret data obtained in an investigation?
10. Bring out the advantages and disadvantages of the investigatory approach?
11. Explain the steps of reporting the data.

2.4.7. References

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 5 : Projects and Experiential Learning

Unit Structure

2.5.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- understand project learning and experiential learning;
- realise how projects and experiential learning help is involving students in learning;
- recognize the different steps of learning through projects;
- understand the phases and components of experiential learning; and
- identify the advantages and limitations of projects and experiential learning.

2.5.2. Introduction

Learning is termed effective only when the learner experiences it and learns. Here is a quote by Confucius

I hear and I forget
I see and I remember
I do and I understand

The above saying directly reflects on the importance of experience and learning out of it. Experience is the true teacher of a man. Hence, all students should be encouraged to learn from various experiences in their life. It refines mind; behaviour and thinking.

A Teacher of science teaching X standard made this statement in the class.

It was heartening to see that one of our neighbors met with a mild heart attack the day before yesterday. He was rushed to the hospital where a cardiologist could save him through medical procedures. Thank God! he survived.

Immediately, an idea emerged in my mind of the teacher to create awareness to her students in this regard. Are you interested to learn more about the excellent organ of the human heart? Students said yes. Topic decided "Our heart & its functions". The teacher said that the class will be divided into small groups and work will be assigned according to the ability of the group.

Then the teacher assigned responsibilities to each of the small groups. Thus goes the project with all the steps. As it is an activity-based project, students learn by doing. Like project learning, we have experiential learning which is also based on student's experiences. Let us learn these two in this unit 5 of Block 2 which elaborates on these two learnings.

2.5.3. Learning Points and Learning Activities

2.5.3.1. Meaning, Definition and Steps of Project, Role of Teacher Advantages, Disadvantages and Example of Topics / Unit Learnt by Project Learning

Meaning, Definition and Steps of Project Learning

a. Meaning: This project learning is based on "learning by doing" and "learning by living" here school curriculum and content of studies are considerate from the students' point of view. It is student-centered learning. The teacher acts as a guide and instructor Students are not forced to do anything and the teacher is not obstructed by curriculum and timetable.

Project learning was devised by Kilpatrick and it was perfected by Stevenson to bring life into school. The essence of this learning is to carry out a useful task in the group in which all the students work cooperatively.

A project stimulates scientific interest, satisfies scientific curiosity, develops scientific attitudes increases self-confidence etc. It takes care of the psychological laws of learning proposed by Thornkide such as the law of readiness, the law of exercise and the law of effects.

b. Definitions:

"A project is a wholehearted purposeful activity proceeding in a social environment"
- Kilpatrick.

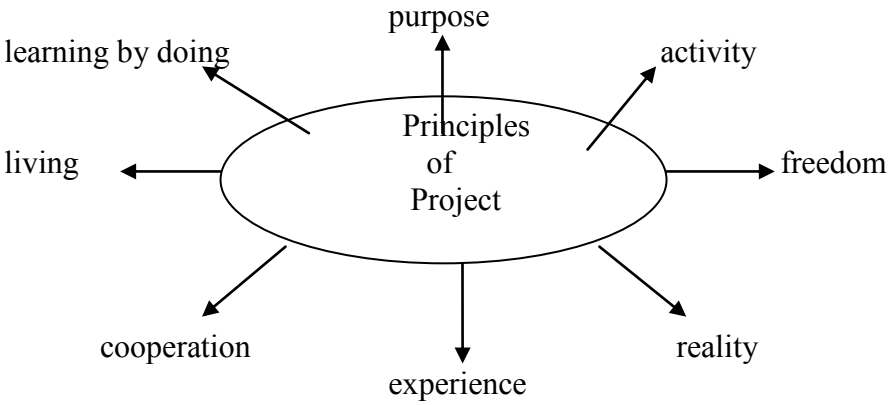
"A project is a problematic act carried to completion in its natural setting" - Stevenson

"A project is a bit of real-life that has been imparted into school" -Ballard

"It is a unit of activity in which students are made responsible for planning and purposing"
- Parker

By analyzing these definitions we see that a project has some purpose and there is planning to achieve the purpose which is achieved in social real and natural situations created in the school.

c. Principles involved in the project method are:



d. Steps involved in a project are:

- Providing a situation
- Choosing & purposing
- Planning
- Executing
- Evaluating
- Recording

Providing a situation: The teacher should provide such situations to the students which may create some problems for them and in which they feel interested to work. "Felt need" should be the basis for a project. The teacher should visualize the requirement and needs of the students.

Choosing & purposing: The purpose of the project should be clearly defined and well understood by students. The projects should be common and acceptable to all.

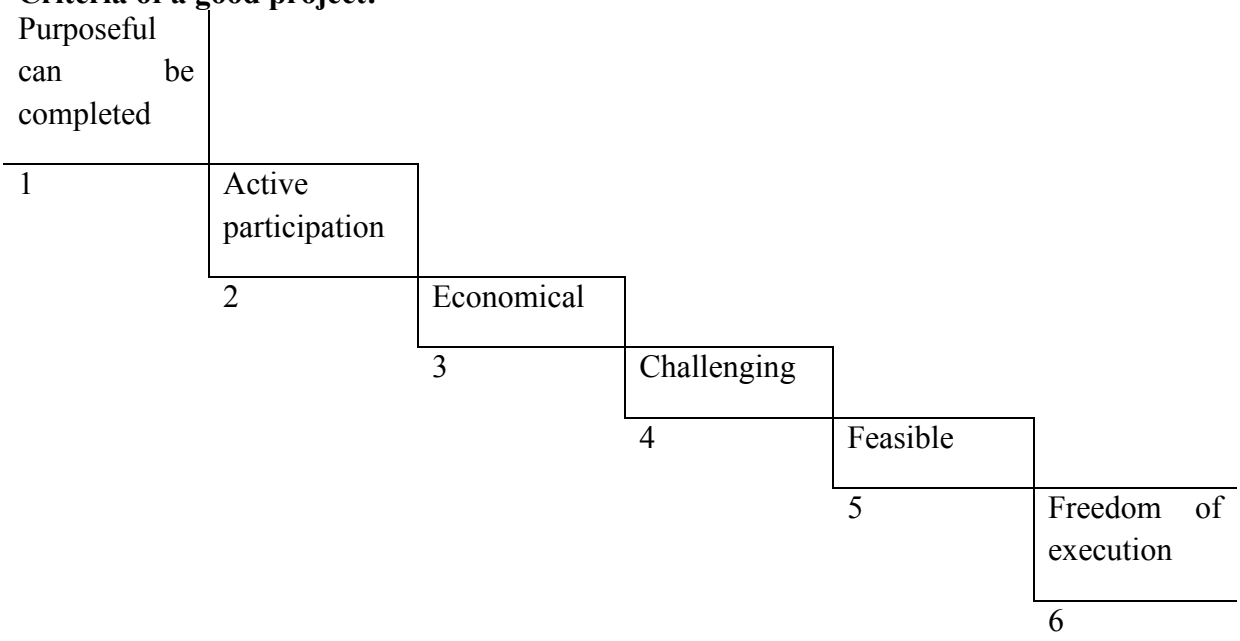
Planning: The quality of a project completely depends upon the quality of planning made. The students should plan out the whole project under the guidance of the teacher. In planning students are supposed to plan for the activities to be taken up like materials to be required, materials collected, place of availability of materials, the procedure to be followed, place of work, distribution on work, the time required and available, expenditure to be met and finally a blueprint of the plan.

Executing: The duties carried out by students and the teacher act as contorted. The students collect information and perform a variety of activities. It is no use in assigning a work student work should be allotted according to the students' abilities. It is the longest step and students need the patience to complete it. A single project promotes a great many activities of knowledge. The teacher should guide, encourage and watch the progress of students and should give instructions wherever needed.

Evaluating: When the project completes students should have a discussion over it with the help of the teacher. The students are instructed to examine their project from the point of view of objectives realized the quality of products, usability of products etc. Finally, the teacher must evaluate and give his graded ratings to the project work.

Recording: The students should keep a complete record of work i.e. planning, discussion, duties, solution and shortcomings of the project so that the next project is easy to accents.

Criteria of a good project:



Role of the Teacher Advantages, Disadvantages and Example of Topics / Unit Learnt By Project Learning

a. Role of the Teacher: As it is the teacher who has to carry out project completion by stimulating student activity. He / She should be a friend & a guide. Creation of democratic atmosphere, development of scientific attitude and the scientific method, encouraging students and making them responsible for doing work entrusted.

b. Advantages: Project learning is based on laws of learning

- develops dignity of labour
- develops social interaction and cooperation
- develops self-confidence
- develops scientific hobbies
- Widens the mental horizon of students.

c. Disadvantages:

- Time-consuming and syllabus cannot be completed.
- Gives superficial knowledge of many things.
- Textbooks are not written on this line
- There is no provision for drill and practice
- There may not be proper development of the subject.

Example

"Students are motivated to select the topic" Our Heart and its functions:

Let us proceed to the completion of the project "our heart and its functions". Because this topic is selected with the willingness of the students and they are grouped by the teacher into subgroups, the steps proceed as below:

Group 1: Members are responsible to collect the theory part of "Heart and its structures" from various books and websites.

Group 2: Members are responsible to collect information on 'functions of Heart' through the videos.

Group 3: Members are responsible to collect information on the importance of the human heart in our body.

Group 4: Members are responsible to collect information on "Heart ailments" – congenital & developed.

Group 5: Members are responsible to collect information on heart ailments from cardiologists in the local place.

Group 6: Members are responsible to collect remedies for heart ailments from cardiologists.

Group 7: Members are responsible to collect information about avoiding heart ailments through yoga and meditation from experts and websites.

Group 8: Members are responsible to collect information on stress management and lifestyle modifications from experts.

Group 9: Members are responsible to collect information on the link between physical health with mental, moral and spiritual health.

All the above groups execute the assignments with the help and guidance of the teacher but with the required freedom. Their presence is not restricted to the class and there existed every freedom to move around to collect needed information care is taken to see that member in the group is cooperative and contributes to the completion of the project. When the teacher is convinced about their execution asks students to assemble and evaluate their work. There will be an exchange of views as each group presents its work. Success and failure of the project are discussed and suggestions for further improvement are given. At the end what all is done from the selection of the project till evaluation will be recorded.

Some of the projects undertaken by the teacher and students of science are.

Our food – the basic necessity
Water – the essence of life
Air – the gift of nature
Biology - the real source of health
Photosynthesis – the process of freshening the environment

Activity: Plan a project activity for your students and write the steps followed

Check Your Progress - 1

1. What is project learning?
2. What are the steps of project learning?
3. Write two advantages and two disadvantages of project learning

2.5.3.2. Meaning and Stages of Experiential Learning, Critical Components of Experiential Learning, Pedagogies Facilitating Experiential Learning, Examples of Experiential Learning, Advantages and Disadvantages

Meaning and Stages of Experiential Learning

a. Meaning of Experiential Learning: Various terms have been used to label the process of learning from experience. John Dewey (Dewey and Dewey 1915) discussed "learning by doing". The term trial and error learning is used to explain inductive learning processes. Rogers (1969, P.5) defined the essence of experiential learning as:

"It has a quality of personal involvement the whole – a person in both his feeling and cognitive aspects being in the learning event"

"Experiential learning exists when a personally responsible participant cognitively, affectively and behaviourally processes knowledge, skills and/or attitudes in a learning situation characterized by a high level of active involvement". (Hoover and whitehead 1975)

b. Phases of Experiential Learning:

The overall Experiential learning task structure is proposed by Wolfe and Byrne (1975). They state that experientially–based approaches involve four phases: design, conduct, evaluation and feedback.

This phase involves the upfront – efforts by the teacher/instructor to set the stage for the experience. Included in this phase are the specifications of learning objectives, the production or selection of activities for participants, the identification of factors affecting student learning, and the creation of a scheme for implementation.

Conduct:

This phase involves maintaining and controlling the design. The design phase may include the creation of a time table for experience, but the conduct phase involves the altering of the original timetable and activities to sustain a favourable learning environment. The important implication of this phase is that the experience is a structured and closely monitored one.

Evaluation:

Evaluation is conducted by the teacher/instructor. But the emphasis here by Wolfe and Byrne is on the provision of opportunities for students to evaluate the experience. Participate should be able to articulate and demonstrate specific learning gained from the design and conduct of the experiences.

Feedback:

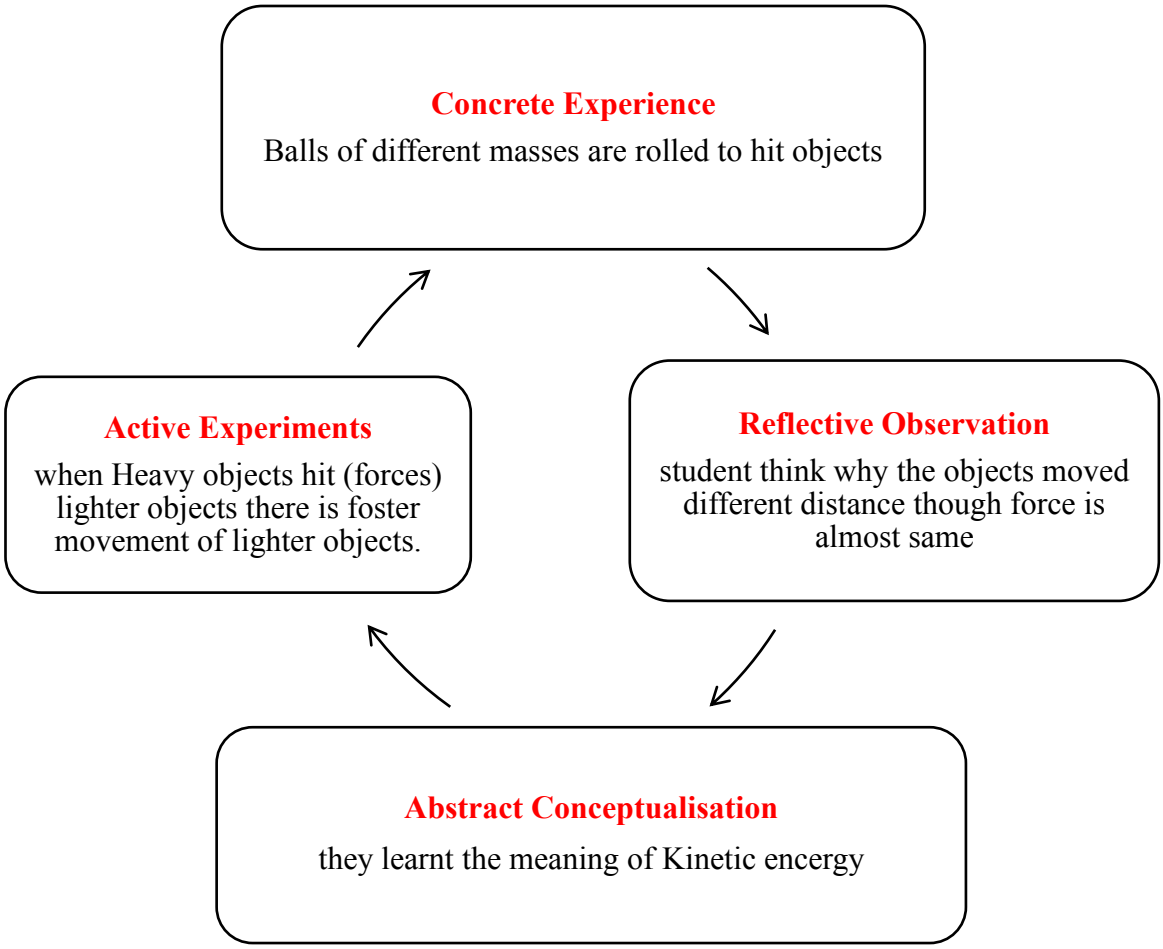
Feedback should be an almost continuous process from the pre-experience introduction through the final debriefing. Included is the monitoring of the process by the

teacher/instructor to foster positive aspects and eliminate those features that are negative. One possible concern in this phase is whether students should have the opportunity to fail. To the extent that we learn from our errors, the freedom to fail may be encouraged.

Learning will be best facilitated when all four phases design, conduct, evaluation and feedback are present and repeated over time. Such a process will be as follows:

The process-oriented version of the Wolfe and Byrne Model

Concept of Kinetic Energy Due to the movement of an object



Critical Components of Experiential Learning

Curriculum related

It should emphasize the benefits of the extracurricular (co-curricular) activities of students. Activities offer a small subset of the student body a chance to develop their leadership skills experientially. Schools actively encourage student clubs to promote activities that involve student participation so that their speaking, discussion, interpersonal and goal setting abilities are developed.

Applied

Experiences occurring without guidance and adequate academic preparation may yield little insight into the general processes taking place. Experiences will not qualify as experiential learning without having the expected educational outcomes articulated and related to the curriculum.

Participative

The student must be involved in the process. Experiential learning is active rather than passive. Rather than just listening to lecture students do role plays or make decisions. (as in simulation game), or perform an analysis of a problem.

Interactive

The interaction involves more than just the teacher/student dyad. It may be student-student, student – parent or student – environment. For example, group decision making in a simulation game, presentations followed by discussions and conducting survey research of local households.

Whole person emphasis

Experiential learning can involve learning on behavioural and affective dimensions as well as cognitive domains. The development of a student's interpersonal and other non-cognitive skills is one of the major expected benefits of experiential learning.

Contact with environment

The term 'experience' implies a real-world contact or at least a real-world-like contact. Some forms of experiential learning such as simulation games, role-playing exercises and case discussions were labeled as surrogate/applied experiential learning. (Most types of experiential learning will fall short of giving students actual decision-making authority). Students should be provided with a variety of situations. Also, it should be noted that different students react quite differently to the same situational cue and that the interaction process should be monitored closely.

Variability and uncertainty

It may be enlightening to a student to listen to a lecture on organizational conflict; however, when it is encountered in the team play of a simulation game and there is no one with the authority to reconcile the opposing views, the messiness associated with organizational conflict becomes very real.

Structured exercise

The experience should be structured and monitored. If there is insufficient autonomy, the willingness to participate may be greatly stifled, on the other hand, if there is no guidance provided, the experience may be largely meaningless in terms of the specific content area for

which the teacher/instructor is responsible. The faculty time commitment to teaching usually increases rather than decreases when students are more participative in and out of the class. An "experience" in itself will not ensure learning; the teacher must ensure that it is a quality experience.

Student evaluation of the experience

Students need to have the opportunity to articulate their thoughts and feelings as to what experience is involving. Even though the teacher is monitoring the experience, the important perceptions of what is happening to reside within the student. Accordingly, these perceptions must be understood and articulated by the students. The design of even highly structured experiential exercises such as simulation games and role-plays are often dynamic, as the designer modifies the exercise upon receiving feedback. A good measure of student's ability to integrate content and process is to have them critique the experience by specifying what should have occurred in the experience as opposed to what was involved.

Feedback

"We learn from experience that men never learn anything from experience." – **George Bernard Shaw**

Kelly (1995) has described the process :

The person who stands agog at each emerging event may experience a series of interesting surprises, but if he does not attempt to discover the recurrent themes, his experience does not amount to much. It is when man gives to see the orderliness in a sequence of events that he beings to experience them from the standpoint of the psychology of personal constructs, it is learning which constitutes experience

This emphasis on process rather than outcome feed has found its way into our approaches to teaching. Even, if we as teachers provide process feedback, students may concentrate on the outcome feedback (grade) and ignore the process feedback (written comments). Most students have come to expect consistency between the two types of feedback, and they are not easily put meaning in the bracket when distinctions between the two are made.

We have a lifetime of experience in learning from outcomes. Outcomes are visible, available and often unambiguous; the process, however, often must be inferred on the part of the teacher. When students do outside survey the process of feedback is almost impossible the teacher has to measure the outcome feedback. Unfortunately, most of our learning based on outcome feedback is based on very small sample size.

Further research (Jenkins and ward 1965; Smedslund 1963; Ward and Jenkins 1965) indicates the people tend to focus on positive outcomes. Feedback is critical for proper learning to take place after an experience. The student should not be allowed to conclude without receiving feedback there is too much evidence that human beings do not do this properly. The process feedback is much more valuable than outcome feedback. Process feedback requires much more monitoring by the teacher, but it is the decision process used that needs to be applauded and critiqued.

Pedagogies Facilitating Experiential Learning

At the low end (those with little or no experiential learning potential) the basic lectures, the seminar discussion, and a library research paper. Those approaches with some experiential learning potential are problem-solving, laboratory, experiential exercises, case discussions, study group discussions and individual ease write-ups, assignments, simulation games, descriptive/analytic field projects and consultative field projects.

Computer-Assisted Instruction

Its focus is on content. Also, it is usually highly controlled, so it is high on structure, similarly, feedback is very likely: in fact, continuous monitoring by the computer is possible.

Live case

An approach that meets the criteria well is the live case approach. A survey research project will be used as a specific example. In most situations, the students are doing this as part of the course requirements or as a survey on solar energy. The typical project requires the students to determine the information needs, obtain background information, develop a questionnaire, pretest it, develop a sampling plan, collect the data, code them, enter them into the computer, analyze the data, write a report and present it to the class. Participation and interactions are thus very prominent in the process as is contact with the environment. The learning taking place involves the cognitive (questionnaire, design and analysis stage), the affective (especially in the data collection stage) and the behavioural (in several stages) dimensions. The variability/uncertainty criterion is very much present, especially in the early stages when the students are trying to understand the nature of the problem being investigated. Guidance from the teacher is crucial. Students provide feedback at various stages, especially at the collection stage.

Examples of Experiential Learning

Example 1: Objective: To enable the students to recognize the transmission of heat in metals through experience.

1. Conduction is a process of transmission of heat in solids.
Take different metal strips – like iron, aluminum, copper, Bronze, Bronze,
A Source of heat
Wax is fixed to all strips at an equal distance

Students will be asked to heat these strips one by one and note when the wax melts at a different distance! They can measure time and tabulate it. They discuss in a group the transmission of heat from colder end to hotter end. They discuss among the group members about changes in transmission of heat in solid metal strips. They can observe which strip conducted heat quickly and which did not. They exchange their views. Students get experience regarding metal strips and conduction of heat. They exchange views with the teacher, friends and assess the learning environment. They participate in the learning process. Their behaviour is observed. As they express their feelings and thinking are assessed. This learning situation develops an interpersonal relationship.

As this content “Conduction” is related to the curriculum what they experience in the laboratory will be applied to a life where the vessels made of different metals will be observed and their hotness will be experienced.

They observe the different metals used to prepare vessels at home. They observe such things in the various social functions held in the community.

Like this students get the opportunity and freedom to learn. To draw meaning out of the experience (though it is an individual personal experience) teacher's guidance is essential. Then only it brings worthy learning.

Students need to get the opportunity to alternate their experiences. Students understand the transmission of heat in metals which are examples of solids. Though the teacher monitors student's activity, the students may have their perceptions which differ among them that must be understood. Students may bring changes in experience if it is inductive. They will be helped by the teacher to generalize rules. Students must experience the pattern or orderliness in the sequence of events they experience. Students can construct their knowledge based on their experiences.

Teacher monitors student activities, interaction and learning. This process and the outcome will be evaluated. Students should evaluate their performance through feedback and self-evaluation. Students may opt for positive feedback than a negative one. But, many times they should be realised that they learn through their errors. Hence, the freedom to fail may be encouraged.

Example 2: Reflection of Sound

1. Curriculum related

The directions in which the sound is incident and is reflected make equal angles with the normal to the reflecting surface at the point of incidence and the three are in the same place.

2. Participative

The teacher arranges the activity to be carried to verify the reflection of sound; students participate in the activity to know the materials required, the arrangement of apparatus, and the process of doing verification of reflection of sound. They change the angle of incidence and angle of reflection of sound. Many trials are taken by students. They experience the way of verifying through individual activity.

3. Interactive

All the students interact with their friends and teacher in the environment. They tabulate the angle of incidence and angle of reflection.

4. Whole person emphasis

Student activities and behaviour is observed by the teacher. They participate by thinking and feeling. Thus it involves the whole personality of students.

5. Contact with environment

The student involves himself in the whole environment interacts with the teacher and other student friends. They develop interpersonal relations.

6. Variability and uncertainty

There may be opposing views that are to be reconciled by the teacher.

7. Structured exercise

The teacher prepares a well-structured evaluation to assess the student's understanding of their learning on 'reflection of sound'.

8. Applied

The learning that is experienced by the students will be related to 'Reflection of light'. There are incidents of reflection of light and sound in our daily life. It has to be examined/observed by students to have experience of it.

9. Student evaluation of the experience

Students evaluate their experience, speak about it and evaluate it. Their success in learning is experienced and also the failure to do so. Success gives feedback to learn more and it develops a mental construct that is enduring.

10. Feedback

Feedback – experience is verbalized by the student.

Feedback – The teacher gives feedback for the process of student activity as well as for their learning through experience (product). Students must be attentive towards the important process feedback, but usually, they concentrate on product (grade) feedback.

Advantages and Disadvantages

Advantages	Disadvantages
1. Student learns by experience (doing).	1. All experience may not be fruitful learning.
2. Student participates actively to learn.	2. It stresses upon the involvement of the learner but if it is not there where is learning by experience
3. Student's cognitive-affective and behaviour aspects are developed.	3.All topics of science are not learnt through experience,
4. Student assesses their learning.	4. It is time-consuming.
5. Students are assessed by the teacher in their process and product of learning.	5. Teacher may not have control over the class.
6. It is an approach to learn science.	6. may not suit lower-level classes.

Check Your Progress - 2

1. Explain the critical components and pedagogies facilitating experiential learning

2.5.4. Let us Summarise

- Project learning was devised by Kilpatrick and perfected by Stevenson to bring life into school.
- A project is a whole-hearted purposeful activity proceeding in a social environment – Kilpatrick.

- Principles of project learning are learning by doing, learning by living, learning by cooperation, learning by activity, learning by freedom, learning reality and learning by experience.
- Students need to evaluate the experience in light of theory and light their own feelings. And, process feedback needs to be provided to the student to complement the outcome received by the student. A wide variety of pedagogies have been labeled as involving experiential learning.

2.5.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1
Answer the following questions
Refer Section 2.5.3.1.

Check Your Progress - 2
Refer Section 2.5.3.2.

2.5.6. Unit end Exercises

A. Write answer to the following in about 3 pages;

1. Explain the meaning, definition and steps of project learning.
2. Describe the steps and components of experiential learning
3. Describe how the project learning is used in a topic/unit from physical science.
4. Describe how experiential learning is used to learn a unit from physical science.
5. Analyse the topic/unit learnt through project / experiential learning from the present VIII and IX standard physical science and write the steps used in a project and experiential learning.

B. Write the answer in about a page:

1. What are the advantages and disadvantages of the project and experiential learning?
2. What will be the role of the teacher in using project and experiential learning?
3. Discuss briefly the feasibility of project learning and experiential learning in the present system of education.

2.5.7. References

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Block 2 : Approaches and Strategies of Learning Physical Science

Unit 6 : Collaborative Approach

Unit Structure

2.6.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- understand the meaning of collaborative learning approach;
- know the need and objectives of the collaborative learning approach;
- identify the importance of collaborative learning approach;
- understand the elements of collaborative learning approach;
- learn the steps of the collaborative learning approach;
- ensure meaningful learning through a collaborative learning approach;
- learn the ways of applying the collaborative learning approach;
- apply collaborative learning Approach in Science Classrooms; and
- Identify the advantages and limitations of the collaborative learning approach.

2.6.2. Introduction

Dear Students, it is heard that the Japanese are very good team workers. That's why as a country Japan has been a renowned and developed country in the world. Likewise, our country needs people who can work in teams. Hence, our learners need to be prepared for the world of work.

You are a teacher in a school where there will be collaborative work. You take responsibility for your teaching work. You discuss with your colleagues' ideas related to teaching and managing the classes. You will communicate your opinions and ideas effectively and try to convince them to your colleagues. You will examine a situation critically by thinking properly. You use your problem-solving ability to solve problems. Your head of the institution will also encourage collaboration among teachers. Your success as a teacher will rely on your academic and social skills in an integrated manner. Hence, your quality and that of all and your school put together in collaboration conveys about the quality of teaching-learning in your school. So, your school may be labeled as a quality imparting school working in a group you may go beyond the caste, creed, religion, region and utilize

the opportunity to develop a friendship with one another which brings cordiality among you, teachers. Sometimes you may need to have a lot of patience and show persistence while completing the work and exhibit a sense of belongingness to your group of teachers. You will be able to represent yourself as teachers of a school who are academically and socially potential. Like this, you represent your school through your collaborative work. It is an indication of togetherness that is unity. Hence, you will be successful in working collaboratively.

Dear student, you will understand what is the fate of those schools (organizations) where there is no collaboration among the teachers.

Unity in diversity should be the motto of a successful organization. In this context, is it not important to develop this collaborative habit in your students also? This 6th unit of Block 2 deals with the collaborative learning approach in science (physical science). We will learn how we can develop this collaboration through science learning.

Activity 1:

Write some instances where you have worked collaboratively.	
1.	4.
2.	5.
3.	6.

2.6.3. Learning Points and Learning Activities

2.6.3.1. Meaning, Need, Objectives and Importance of Collaborative Learning Approach

Meaning of Collaborative Learning Approach

Collaborative learning is a parasol term for a variety of instructive tactics involving a joint rational effort by students and teachers together. In this environment all are working in a group of two or more, mutually working on a common problem by collecting useful material and knowledge and disseminating the same in the group for a better outcome. The environment offers to showcase the strength of an individual and allows developing their weaker skills.

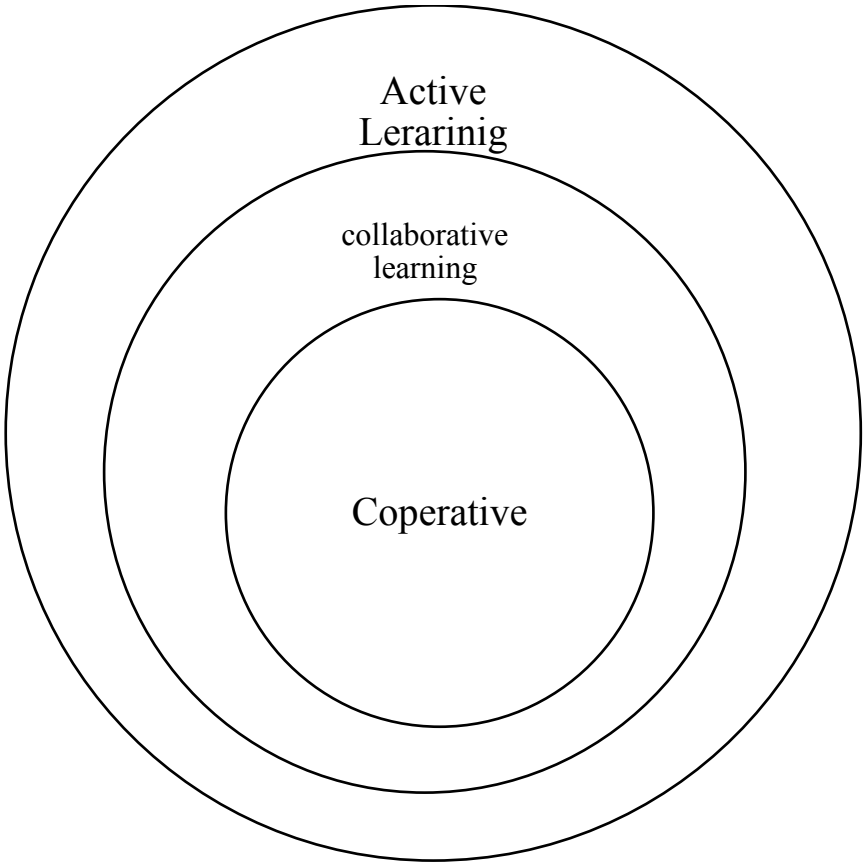
Collaborative Learning (CL) is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product. In the CL environment, the learners are challenged both socially and emotionally as they listen to different perspectives, and are required to articulate and defend their ideas. In so doing, the learners begin to create their unique conceptual frameworks and not rely solely on an expert's or a text's framework. In a CL setting, learners have the opportunity to converse with peers, present and defend ideas, exchange diverse beliefs, question other conceptual frameworks, and are actively engaged (Srinivas, H., 2011).

Memory retention for all age groups focuses that 50% retention on what we see 70% retention on what we discuss and 90% retention on what we discuss and do. Rationally around 75% of learning can take place by using discussion, sharing, and doing. This promotes the activities in today's era to participate in a discussion group, sharing the

knowledge and experience, and doing real experiments with proper sharing of the resources and thoughts. This makes the environment healthier and makes learning more strong collaboratively.

Collaborative learning is a technique that involves a group of students working together to impact learning positively. Working together and learning together always results in more learning outcomes than working or learning individually.

Active learning is the superset of collaborative learning which involves talking, listening, writing and reading with individual involvement in the learning pedagogy. Collaborative learning involves the active participation of a group where the interaction and implementation take place in the pedagogy. The figure below illustrates the scenario for active learning, collaborative learning and cooperative learning.



Rapid developments in information and communications technologies (ICT) and evolving learner behaviours require tech resource providers to continuously re-evaluate their approaches to pedagogy, both in the physical and virtual classroom spaces. The concept of collaborative learning evolved from a virtual classroom where people having similar interests and similar areas to research share their ideas and knowledge. This working in a group improves both learnings of individuals as well as the learning of their peers as healthy knowledge sharing takes place in the environment.

Need and Objectives of Collaboration Learning Approach

Learners of the 21st century should have an opportunity to experience virtual collaboration and teamwork. One must be equipped enough to communicate across social and structural boundaries using technology. To address this need, instructors increasingly

incorporated virtual learning environments in traditional teaching and learning environment. Another benefit of using virtual collaboration as a strategy to teach and learn is the ability to bring together heterogeneous participants and learners to a diversity of cultures, opinions and communication styles.

By indulging in a collaborative learning environment, learners can reach each other to solve problems, can share knowledge and resources can build team skills and can lend towards deeper learning skills.

Learners can lead each other to a great team where member can exchange their ideas and build a deeper understanding environment. A collaborative learning environment allows reaching out to one another to solve many complex problems and sharing expensive resources

Importance of Collaboration Learning Approach

- In the construction of knowledge, the social aspect is also involved in the sense that knowledge needed for a complex task can reside in a group situation. In this context, collaborative learning provides room for negotiation of meaning sharing multiple views, and changing the internal representation of ideas to external reality.
- In the collaborative setup, each learner individually and socially constructs meaning as she learns.
- Collaborative learning enhances motivation to learn and increases the depth of understanding.
- In the group setting, learners develop a positive attitude towards the learning and materials on which they work as they contribute to it.
- Learning is more effective as students themselves take care to resolve any conflicting observations and opinions.
- Learning is more effective as students themselves take care to resolve any conflicting observations and opinions.
- It also allows them to apply the concepts in a real-life situation and to learn to solve the problem in multiple ways.
- Disinterested students readily learn from their peers as their learning problems and issue are better appreciated by their peers.
- Working in a group, students move beyond the caste, creed, region and get the opportunity to develop a friendship with each other.
- Students learn the qualities of doing collaborative and teamwork, patience, the persistence of effort, completing the task within the set time frame and a sense of belongingness to the group as well as to their learning. They get to know who they are in the opinion of others and identify their own social and academic potential.

Check Your Progress - 1

1. What is collaborative learning?
2. How collaborative learning differs from active learning?
3. From where this concept of collaborative learning has evolved?
4. What is the need for collaborative learning?
5. What is the objective of collaborative learning?

2.6.3.2. Elements, steps of Collaborative Learning Approach and Ensuring Meaningful Learning through Collaborative Learning Approach

Elements of Collaboration Learning Approach

The elements of collaborative learning depend on the domain in which it is considered. Here in the teaching-learning environment, the elements and the advantages are considered for 21st-century learners.

Key elements on which teaching learning emphasis in the 21st century are:

- Learning abilities of the learner
- Learning tools used by the learner
- Process of teaching-learning in the context
- Assessment that measures the skills and
- A vast pool of content available.

Also, the major aspects that support the smooth collaborative learning environments are:

- Learners readiness in working in a collaborative environment
- Learners viewpoints
- Learners cooperation and
- Learners adaptivity.

Constructing a learning environment together is the fundamental objective of collaborative learning. The major elements of the Collaborative learning Approach are:

Johnson and colleagues (1990) pointedout 5 basic elements in CL.CL is not simply a synonym for members working in groups. A learning exercise only qualifies as CL to the extent that the following elements are present:

1. **Perceived positive interdependence:** Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences. Members need to believe that they are linked with others in a way that ensures that they all succeed together. Positive interdependence is the belief by each individual that there is value in working with other members and that both individual learning and work products will be better as a result of collaboration.
2. **Considerable interaction:** Members help and encourage each other to learn. They do this by explaining what they understand and by gathering and sharing knowledge. Group members must be done interactively providing one another with feedback, challenging one another's conclusions and reasoning, and perhaps most importantly, teaching and encouraging one another.
3. **Individual accountability and personal responsibility:** All members in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned.
4. **Social skills:** Members are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.
5. **Group self-evaluating:** Team members set group goals, periodically assess what they are doing well as a team, and identify changes they will make to function more effectively in the future.

The above elements distinguish traditional group learning from the collaborative learning environment. The presence of every element may increase the thoroughness of the entire system. The active presence and effort of an individual affect the overall performance of the group as a whole. The overall performances and efforts must be felt and be accessible to the entire group as a whole. Skills of an individual may be used in a group that may lead other members to utilize to achieve the common objective of a group which is learning. Effective communication and sharing of individual's skills and knowledge always enhances the overall learning environment and makes the teaching-learning environment healthy successful implementation of collaborative work for the educational domain likely to provide add-on input for the better outcome to the students as well as teachers. It allows explicit procedures that encourage students to work together. It helps the teacher to monitor groups, decisions about the learning of the student in the teaching-learning environment.

Activity 2: Select any topic from the textbook that you plan to transact during your practice teaching. Discuss in a group of four members, how you will design teaching-learning experiences to transact the topic. After about 10 minutes discuss your experiences of group work on the following lines:

- Did everybody get the opportunity to share her idea?
- Do you feel sharing of ideas enriched planning of teaching
- How is your overall experience with this collaborative work?

Steps of Collaborative Learning Approach

- Problem issue or concept is identified to be dealt within a group situation. It may be small or big, simple or complex depending upon the learning environment and teaching learning process.
- Formation of groups say (4 to 6 students) is facilitated to take up the task of their choice.
- There is the exchange of ideas, discussion on the issue at hand or performance of activities or experiments to clarify the concept in a group situation. Sharing of ideas facilitates visiting and revisiting the concepts.
- The teacher facilitates their interactions directed towards the set goal within the stipulated time frame.
- Learning evidence is assessed throughout the teaching-learning process and feedback is provided to all groups of learners.

Ensuring Meaningful Learning through Collaborative Learning Approach

- Ensure that the group is heterogeneous. There should be learners learning with different paces and styles in a group.
- However, keep grouping patterns flexible and consider the choice of the learners also.
- Every time keep on changing the members of the group.
- Facilitate them to form group rules. If there is a disagreement, consensus should emerge.
- Make a point that the group leader will facilitate the work of the group and keep them organized. The leader should not dominate over other members.
- Tell one student of the class to pass on the name of group members and group leaders on a piece of paper for your record.
- While assessing, you may give the same grade to all members of the group as far as possible. This will prompt the learner to learn with greater pace to motivate other learners to perform.

- It will be convenient for you if you start this approach after 2 to 3 months after the session starts. It will give you enough time to identify the academic and social skills of all the students and help you to facilitate them informing the group.
- Ensure that members of all groups should be made responsible for their work. All members should remain open to each other's ideas and get equal opportunities to share their ideas and work.
- All members should be given the liberty to express their ideas freely and work cohesively towards achieving the goal.

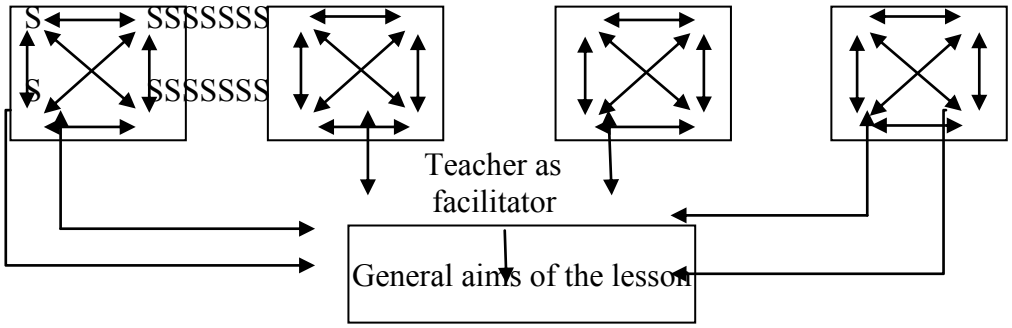


Fig. A collaborative learning set up in the classroom (S-Student).

Rohit is a student, the teacher interacted with his class to formulate some rules for them when working collaboratively. The rules emerged after consensuses of the class were as follows:

- Speak clearly and in a complete sentence.
- Listen to each other's ideas attentively without interruption.
- Be polite to others. Wait for your turn.
- Give value to each other's idea
- Evaluate each other's ideas and communicate them to the respective members.
- Follow the rules once framed by you. If you feed to bring any change, do with the consensus of all.
- If it is an activity or experiment to be performed in the group, everybody will get the opportunity to try her hand at it by turn.

The common myths in the collaborative learning environment are as follows:

- Sitting together and learning together
- Learning in a group with only a few are working and
- Sharing content that might not be re-learned.

The outcome of the collaborative environment can be measured based on mainly three criteria carried out continuously:

- Individual assessment
- Team assessment
- Expediter/system assessment

Check Your Progress - 2

1. Which are the key and major elements of collaborative learning for 21st-century learners?
2. What are the steps of the collaborative learning approach?
3. What are the rules formulated by the teacher with students for collaborative learning?

2.6.3.3. Ways of Applying Collaborative Learning Approach, Advantages and Limitations of Collaborative Learning Approach

Ways of Applying Collaboration Learning Approach

There are various ways in which the collaborative learning approach may be applied such as given below:

i. Brain Storming

- A problem is identified
- Small groups are formed
- All members are encouraged to find the solution and express their ideas
- No idea is criticized but can be modified
- As many as possible ideas may be given

Example:

- How can we minimize the wastage of water?
- How can we prevent soil pollution?
- How can we prevent air pollution?

ii. Task Group

- A problem is identified
- Small groups are formed
- Each group of the class is assigned
- A specific task to be completed within a time frame
- The task of each group is evaluated by other groups.
- Completion of the task is the responsibility of all

Example:

- Collect information on the solar system and prepare a model.
- Collect information on nuclear fission and prepare a model of it.

Skill Developed:

Collecting information, taking responsibility, the delegation of work, initiative ness, planning skills, preparing skills, accomplishment, evaluation and emotional skills

iii. Inquiry group

- The teacher creates a situation of some discrepant event during the teaching-learning process.
- Students are helped to realize that there exists a problem, a solution of which is to be inquired.
- Different groups work on the same problem and may come up with a different hypothesis, solutions and conclusion.
- To get involved in the inquiry, learners may discuss, share their ideas, derive the equations, perform an activity, experiments and solve numerically.

Example:

1. How would our life be affected if the force of friction suddenly vanishes?
2. How would be our life if the earth's gravitational force will not work for a few minutes?

Skill Developed:
Problem-solving skill, inquiry skill, analysis, synthesis and evaluation

iv. Tutorial Group

- The teacher facilitates the formation of the group according to students ability
- A concept is identified by the teacher which can be learned in a group setting
- A student having a good understanding of the concept is identified as a group leader by the teacher. Opportunities should be provided to various students in turn.
- The group leader is assigned the job of facilitating learning to all members of her group.
- The group leader asks questions with the members and encourages them to discuss their learning difficulties with her.

Example:

1. Determine unknown resistance using a meter bridge
2. Verification of image formation in a convex lens.

Activity 3: Form four groups in the class and work collaboratively to identify the cause of pollution of the river in or near your city. Perform this activity through the following approaches

a) Brainstorming
b) Task group
c) Inquiry group
d) Tutorial group

After performing this activity share your experience and ideas in the class.

Difference Between Collaborative Learning and Cooperative Learning

Collaborative learning encourages self-governance, shouldering responsibilities according to one's interest and skill. Each member is accountable for the task. It is convenient to use the former setting when a task can be done in one way only. E.g. learning formulae or writing chemical equations as given in the textbook. Solving a problem, experimenting/activity/project demands collaborative set up.

Advantages and Limitations of Collaboration Learning Approach

A. few of the advantages of collaborative learning are:

- Knowledge building
- Learner centric methodology
- Exchange, debating, negotiating ideas
- Develops highly communicative discussion skills
- Develops social interaction skills
- Develops higher-level thinking
- Encourages and improves the multidimensional problem-solving skills
- Enriched course materials
- Immediate feedback
- On-demand interaction and support
- Flexibility etc.

Increasing student satisfaction level and promoting the positive teaching learning attitude amongst the group are a few of the nonfunctional benefits of the collaborative learning environment.

Limitation of Collaborative Learning Approach

- Teacher's dominance is reduced: The control is passed onto the students themselves. As a result, some teachers may feel like losing control.
- If the work of the groups is not properly monitored: misconceptions and naive concepts may breed in the thinking of the learners.
- A shy student may not participate actively in the group, the interaction of all members need to be continuously monitored.
- It may be difficult to check and recheck the work of all the groups working at one-time inexperienced teachers.
- Very meticulous planning is required for meaningful learning to take place. Various aspects need to be considered - needs, interest and abilities of each student scope of the active concept to be discussed in the group, classroom management, group dynamics of the class etc.

Activity 4:

ISRO is a renowned Indian space programme that emerged as the dream child of Dr. Vikram Sarabhai. There are many space programmes like preparing and launching rockets and satellites. Now India is one of the 7 countries in the world having a space programme. There are many milestones. One of them is Chandrayan -2. It is an example of the teamwork of scientists in good numbers. Manufacture of the complicated Vikram Lander and Pragyam Rover is itself a hilarious task. There was a lot of collaboration among scientists. They need to be appreciated for this amazing and tedious task. Before and after the launch of these Pragyam and Vikram vehicles scientists must have experienced that their hard work will definitely give results. But, the vehicle lost its signals at a distance of 2 K.M. from the moon. Very sad news! It doesn't mean that scientists' efforts are in vain. A committee of scientists will examine why is such failure of not landing on the moon?

You as a teacher try to follow these incidents and collect information from the media as to what happened? After all, it is a genuine scientific venture bringing laurels to India. (Go through newspaper and T.V. News of 7th and 8th September 2019)

Check Your Progress - 3

1. Which are the ways of applying a collaborative learning approach?
2. What are the advantages and limitations of collaborative learning?

2.6.4. Let us Summarise

- Collaborative learning is a technique that involves a group of students working together to impact learning positively. Working together and learning together always results in more learning outcomes than working or learning individually.
- Collaborative learning is a parasol term for a variety of instructive tactics involving a joint rational effort by students, students and teachers together.
- Active learning is the superset of Collaborative learning which involves talking, listening, writing and reading with an individual in learning pedagogy. Collaborative learning involves the active participation of a group where the interaction and implementation take place in pedagogy.

- The concept of Collaborative learning is evolved from a virtual classroom' where people having similar interest and similar area to research share their ideas and knowledge
- Learners of the 21st century should have an opportunity to experience virtual Collaboration and teamwork. To bring together heterogeneous participants and learners to a diversity of cultures, opinions and communication styles.
- The objective of Collaborative learning is to increase productivity towards the common goal in terms of improving learning skills and generating knowledge in the group.
- Constructing the learning environment together is a fundamental objective of collaborative learning.
- The key elements of Collaborative learning for the 21st century are the learning abilities of the learner, learning tools used by the learner, the process of teaching learning in the context, the assessment that measures the skills and vast post of content available.
- The major elements are learner's readiness in working in a Collaborative environment, learner's viewpoints, learners cooperation and learners adaptively.

The steps of the Collaborative learning approach are:

a) Identification of problem, issue or concept.
b) Formation of groups.
c) Exchange of ideas, discussion, performance of experiments, sharing ideas . . . .
d) Teacher facilitation to reach the set group at the stipulated time.
e) Assessment of learning evidence and providing feedback to all group members.

- The rules formulated by a teacher with student's consensus are: speak clearly with complete sentence listen with attention. Be positive and wait for your turn, give value to each other's ideas, evaluate ideas, follow rules framed by you, an opportunity for everyone to try a hands-on experiment.
- The way of applying the Collaborative learning approach is brainstorming. Task group, inquiry group and tutorial group.
- A few advantages of collaborative learning are knowledge building, learner-centric, exchange of ideas, communicative discussion, social interaction skills, higher-level thinking, and multidimensional skills problem-solving skills. Enriched course materials, immediate feedback, flexibility etc.
- Limitations are: Teachers' feel like losing control, fails if groups are not properly monitored shy students may not participate difficult for the inexperienced teacher, materials planning is required

2.6.5. Answer to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1. Collaborative learning is a parasol term for a variety of instructive tactics involving a joint rational effort by students, students and teachers together.
2. Collaborative learning is a technique that involves a group of students working together to impact learning positively. Working together and learning together always results in more learning outcomes than working or learning individually.
3. Active learning is the superset of Collaborative learning which involves talking, listening, writing and reading with an individual in learning pedagogy. Collaborative

learning involves the active participation of the group where the interaction and implementation take place in pedagogy. Collaborative learning involves the active participation of the group where the interaction and implementation take place in pedagogy.

4. The concept of Collaborative learning is evolved from a virtual classroom' where people having similar interests and similar areas to research share their ideas and knowledge.
5. To expose the learners of the 21st century to experience virtual collaboration and teamwork. To bring together heterogeneous participants and learners to a diversity of cultures, opinions and communication styles.
6. The objective of collaborative learning is to increase productivity towards the common goal in terms of improving learning skills and generating knowledge in the group.

Check Your Progress - 2

1. The key elements of Collaborative learning for the 21st century are the learning abilities of a learner, learning tools used by the learner, the process of teaching learning in the context, the assessment that measures the skills and vast pool of content available.
2. The major elements are learner's readiness in working in a Collaborative environment, learner's viewpoints, learners cooperation and learners adaptability.
3. The steps of the Collaborative learning approach are:
    a. Identification of problem, issue or concept.
    b. Formation of groups.
    c. Exchange of ideas, discussion, the performance of experiments, sharing ideas.
    d. Teacher facilitation to reach a set goal at a stipulated time.
    e. Assessment of learning evidence and providing feedback to all group members.
4. The rules formulated by the teacher with student's consensus are: speak clearly with complete sentence listen with attention. Be positive and wait for your turn, give value to each other's ideas, evaluate ideas, follow rules framed by you, the opportunity to everyone to try a hands-on experiment.

Check Your Progress - 3

1. The way of applying the Collaborative learning approach is brainstorming. Task group, inquiry group and tutorial group.
2. A few advantages of collaborative learning are: knowledge building, learner centric, exchange of ideas, communicative discussion, social interaction skills, higher-level thinking, and multidimensional skills, problem-solving skills. Enriched course materials, immediate feedback, flexibility etc.
3. Limitations are Teachers' feel like losing control, fail if groups are not properly monitored shy students may not participate difficult for the inexperienced teacher, materials planning is required.

2.6.6. Unit end Exercises

A. Answer the following in 3 to 4 pages

1. What collaborative learning approach?
2. How it is different from Active learning and collaborative learning? What are the need and objectives of the collaborative learning approach?

3. Why is the collaborative learning approach is important? What are its key and major elements supporting collaborative learning?
4. Explain the steps of the collaborative learning approach. How do you ensure meaningful learning through a collaborative approach?
5. Explain the different ways of collaborative learning approach with one example each.

B. Answer the following in a page:

1. Write the advantages and limitations of the collaborative learning approach.
2. Differentiate (i) task group, (ii) Tutorial group, (iii) Inquiry group
3. What are the features of Brainstorming? Explain with the help of an example.
4. Why there is a need to help the learner to learn through collaboration?

2.6.7. References

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