



# Teachers' Handbook

## Volume 2 : Scientific Literacy



A Collaborative effort of CBSE, KVS, NVS and  
Department of Education, Chandigarh Administration  
Under the guidance of MHRD



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केंद्रीय माध्यमिक शिक्षा बोर्ड  
**CENTRAL BOARD OF SECONDARY EDUCATION**

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# CHAPTER 1

## SCIENCE EDUCATION



*To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.*

**Albert Einstein**

All educators including science teachers have the responsibility of expanding their students' horizons beyond the classroom. The best way to do this is to utilize one's expertise as well as all available resources to transact and extend the classroom curriculum to create an impact that can stay with students throughout their lives. A reconstruction of our approaches and pedagogical innovations needs to be done with an unprecedented zeal to arrive at pragmatic solutions to the complex scenario that Science education currently is in.

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

### 1.1 Validity of Science Curriculum

The basic criteria of validity as per NCF 2005 are :

- **Cognitive Validity** - requires that the content, process, language and pedagogical practices of the curriculum are age-appropriate, and within the cognitive reach of the child.
- **Content Validity** - requires that the curriculum must convey significant and correct scientific information. Simplification of content must not be so trivialised as to convey something flawed and/or meaningless.
- **Process Validity** - requires that the curriculum should engage the learner in acquiring the methods and processes that lead to generation and validation of scientific knowledge and nurture the natural curiosity and creativity of the child in science.
- **Historical Validity** - requires that the science curriculum be informed by a historical perspective, enabling the learner to appreciate how the concepts of science evolve over time. It also helps the learner to view science as a social enterprise and to understand how social factors influence the development of science.
- **Environmental Validity** - requires that science be placed in the wider context of the learner's environment, local and global, enabling him/her to appreciate the issues at the interface of science, technology and society, and equipping him/her with the requisite knowledge and skills to enter the world of work.

\* **NCF- National Curriculum Framework**



- **Ethical validity**- requires that the curriculum promotes the values of honesty, objectivity, cooperation, and freedom from fear and prejudice, and inculcates in the learner a concern for life and preservation of the environment

In keeping with these 6 criteria, the objectives of teaching science for the upper primary, secondary and higher stage are defined as under.

## 1.2 The Objectives of Teaching Science:

- At the **upper primary stage**, the child should be engaged in learning principles of science through familiar experiences, working with hands to design simple technological units and modules (e.g. designing and making a working model of a windmill to lift weights) and continuing to learn more on environment and health through activities and surveys. Scientific concepts are to be arrived at mainly from activities and experiments. Science content at this stage is not to be regarded as a diluted version of secondary school science. Group activities, discussions with peers and teachers, surveys, organization of data and their display through exhibitions, etc. in schools and neighbourhood are to be an important component of pedagogy.
- At the **secondary stage**, the students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological modules than at the upper primary stage, and involved in activities and analysis on issues surrounding environment and health. Systematic experimentation as a tool to discover/verify theoretical principles, and working on locally significant projects involving science and technology are to be important parts of the curriculum at this stage.
- At the **higher secondary stage**, science should be introduced as a separate discipline, with emphasis on experiments/ technology and a focus on problem-solving.

*(Source: Position Paper - National Focus Group - Teaching of Science – NCERT)*

## 1.3 Curricular Expectations

Science curriculum at the upper primary stage intends to develop:

1. Scientific temper and scientific thinking.
2. An understanding of the nature of scientific knowledge i.e., testable, unified, parsimonious, amoral, developmental and creative.
3. Process skills of science which includes observation(s), posing question(s), searching various resources of learning, planning investigations, hypothesis formulation and testing, using various tools for collecting, analysing and interpreting data, supporting explanations with evidence, critically thinking to consider and evaluate alternative explanations, reflecting on their own thinking.
4. Appreciation of the historical aspects of the evolution of science.
5. Sensitivity towards environmental concerns.
6. Respect for human dignity and rights, gender equity, values of honesty, integrity, cooperation and concern for life.

*(Source: Learning Outcomes at Elementary Stage by NCERT)*

## 1.4 Learning Outcomes

Learning Outcomes are assessment standards indicating the expected levels of learning that children should achieve for that class. These outcomes can be used as check posts to assess learning at different points of time. The learning outcomes would help teachers to understand the learning levels of children in their respective classes individually as well as collectively. Learning outcomes should be the point of reference for conducting achievement surveys. Hence, the defined Learning Outcomes must be shared with parents and community at large.





## CLASS VI - SCIENCE

### Learner

- ❖ **Identifies** materials and organisms, such as plant fibres, flowers, based on observable features i.e. appearance, texture, function, aroma etc.
- ❖ **Differentiates** materials and organisms, such as fibre and yarn; tap and fibrous roots; electrical conductors and insulators; based on their properties, structure and functions
- ❖ **Classifies** materials, organisms and processes based on observable properties e.g. materials as soluble, insoluble, transparent, translucent and opaque; changes as can be reversed and cannot be reversed; plants as herbs, shrubs, trees, creeper, climbers; components of habitat as biotic and abiotic; motion as rectilinear, circular, periodic etc.
- ❖ **Conducts simple investigations** to seek answers to queries e.g. What are the food nutrients present in animal fodder? Can all physical changes be reversed? Does a freely suspended magnet align in a particular direction?
- ❖ **Relates processes** and phenomena with causes e.g. deficiency diseases with diet; adaptations of animals and plants with their habitats; quality of air with pollutants etc.
- ❖ **Explains processes** and phenomena e.g. processing of plant fibres; movements in plants and animals; formation of shadows; reflection of light from a plane mirror; variations in the composition of air; preparation of vermicompost etc.
- ❖ **Measures** physical quantities and expresses in SI units e.g. length.
- ❖ **Draws labelled diagrams / flow charts** of organisms and processes e.g. parts of flowers; joints; filtration; water cycle etc.
- ❖ **Constructs models** using materials from surroundings and explains their working e.g. pinhole camera, periscope, electric torch etc.
- ❖ **Applies learning** of scientific concepts in day-to-day life e.g. selecting food items for a balanced diet; separating materials; selecting season-appropriate fabrics; using compass needle for finding directions; suggesting ways to cope with heavy rain/ drought etc.
- ❖ **Makes efforts to protect the environment** e.g. minimising wastage of food, water, electricity and generation of waste; spreading awareness to adopt rainwater harvesting; care for plants etc.
- ❖ **Exhibits creativity** in designing, planning, making use of available resources etc.
- ❖ **Exhibits values** of honesty, objectivity, cooperation, freedom from fear and prejudices.

## CLASS VII - SCIENCE

### Learner

- ❖ **Identifies** materials and organisms, such as animal fibres; types of teeth; mirrors & lenses, on the basis of observable features i.e. appearance, texture, functions etc.
- ❖ **Differentiates** materials and organisms such as digestion in different organisms; unisexual and bisexual flowers; conductors and insulators of heat; acidic, basic and neutral substances; images formed by mirrors and lenses etc. on the basis of their properties, structure and function.
- ❖ **Classifies** materials and organisms based on properties/characteristics e.g. plant and animal fibres; physical and chemical changes.
- ❖ **Conducts simple investigations** to seek answers to queries e.g. Can extract of coloured flowers be used as acid-base indicator? Do leaves other than green also carry out photosynthesis? Is white light composed of many colours.



- ❖ **Relates processes** and phenomena with causes e.g. wind speed with air pressure; crops grown with types of soil ; depletion of the water table with human activities etc.
- ❖ **Explains processes and phenomena** e.g. processing of animal fibres; modes of transfer of heat; organs and systems in humans and plants ; heating and magnetic effects of electric current etc.
- ❖ **Writes word equations** for chemical reactions e.g. acid-base reactions; corrosion; photosynthesis; respiration etc.
- ❖ **Measures and calculates** e.g. temperature; pulse rate; speed of moving objects; time period of a simple pendulum etc.
- ❖ **Draws labelled diagrams/flow charts** e.g. organ systems in humans and plants; electric circuits; experimental set-ups ; the life cycle of the silk moth etc.
- ❖ **Plots and interprets graphs** e.g. distance-time graph.
- ❖ **Constructs models** using materials from surroundings and explains their working e.g. stethoscope; anemometer; electromagnets; Newton's colour disc etc.
- ❖ **Discusses and appreciates** stories of scientific discoveries.
- ❖ **Applies learning** of scientific concepts in day-to-day life e.g. dealing with acidity; testing and treating soil; taking measures to prevent corrosion; cultivation by vegetative propagation; connecting two or more electric cells in proper order in devices; taking measures during and after disasters; suggesting methods for treatment of polluted water for reuse etc.
- ❖ **Makes efforts to protect the environment** e.g. following good practices for sanitation at public places; minimising generation of pollutants; planting trees to avoid soil erosion; sensitising others with the consequences of excessive consumption of natural resources etc.
- ❖ **Exhibits creativity** in designing, planning, making use of available resources etc.
- ❖ **Exhibits values** of honesty, objectivity, cooperation, freedom from fear and prejudices.

## CLASS VIII - SCIENCE

### Learner

- ❖ **Differentiates** materials and organisms, such as natural and human-made fibres; contact and non-contact forces; liquids as electrical conductors and insulators; plant and animal cells; viviparous and oviparous animals, on the basis of their properties, structure and functions.
- ❖ **Classifies** materials and organisms based on properties/ characteristics e.g. metals and nonmetals; kharif and rabi crops; useful and harmful microorganisms; sexual and asexual reproduction; celestial objects; exhaustible and inexhaustible natural resources etc.
- ❖ **Conducts simple investigations** to seek answers to queries e.g. what are the conditions required for combustion? Why do we add salt and sugar in pickles and murabbas? Do liquids exert equal pressure at the same depth?
- ❖ **Relates processes** and phenomenon with causes e.g. smog formation with the presence of pollutants in the air; deterioration of monuments with acid rain etc.
- ❖ **Explains processes and phenomena** e.g. reproduction in humans and animals; production and propagation of sound; chemical effects of electric current; formation of multiple images; structure of flame etc.
- ❖ **Writes word-equations** for chemical reactions e.g. reactions of metals and non-metals with air, water and acids etc.





- ❖ **Measures angles** of incidence and reflection etc.
- ❖ **Prepares slides of microorganisms** onion peel, human cheek cells etc. and describes their microscopic features.
- ❖ **Draws labeled diagrams/flow charts** e.g. structure of the cell, eye, human reproductive organs; experimental set-ups etc.
- ❖ **Constructs models** using materials from surroundings and explains their working e.g. ekara, electroscope, fire extinguisher etc.
- ❖ **Applies learning** of scientific concepts in day-to-day life, e.g. purifying water; segregating biodegradable and non-biodegradable wastes; increasing crop production using appropriate metals and non-metals for various purposes; increasing/ reducing friction; challenging myths and taboos regarding adolescence etc.
- ❖ **Discusses and appreciates** stories of scientific discoveries.
- ❖ **Makes efforts to protect the environment** e.g. using resources judiciously; making controlled use of fertilizers and pesticides; suggesting ways to cope with environmental hazards etc.
- ❖ **Exhibits creativity** in designing, planning, making use of available resources etc.
- ❖ **Exhibits values** of honesty, objectivity, cooperation, freedom from fear and prejudice.

*(Source: Learning Outcomes at the Elementary Stage, NCERT)*

## CLASS IX - SCIENCE

### Learner

- ❖ **Differentiates** materials/objects/organisms/phenomena/processes based on properties/ characteristics.
- ❖ **Classifies** materials/objects/organisms/phenomena/processes based on properties/ characteristics.
- ❖ **Plans and conducts** investigations/ experiments to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own.
- ❖ **Relates** processes and phenomena with causes/ effects.
- ❖ **Explains** processes and phenomena.
- ❖ **Calculates** using the data given.
- ❖ **Draws labelled diagrams/ flow charts/ concept maps/graphs** such as biogeochemical cycles, cell organelles and tissues, the human ear, distance-time and speed-time graphs, distribution of electrons in different orbits, the process of distillation/ sublimation etc.
- ❖ **Analyses and interprets** graphs/ figures etc.
- ❖ **Uses scientific conventions/ symbols/ equations** to represent various quantities/ elements/ units.
- ❖ **Measures physical quantities** using appropriate apparatus/instruments/ devices.
- ❖ **Applies learning** to hypothetical situations.
- ❖ **Applies scientific** concepts in daily life and solving problems.
- ❖ **Derives** formulae/ equations/ laws.
- ❖ **Draws conclusions** such as classification of life forms is related to evolution, deficiency of nutrients affects physiological processes in plants, matter is made up of particles, elements combine chemically in a fixed ratio to form compounds, action and reaction act on two different bodies etc.
- ❖ **Describes** scientific discoveries/ inventions.



- ❖ **Designs** models using ecofriendly resources.
- ❖ **Records & reports** experimental data objectively and honestly. Exhibits values of honesty/ objectivity/ rational thinking/ freedom from myths/superstitious beliefs while taking decisions, respect for life etc.
- ❖ **Communicates** the findings and conclusions effectively.
- ❖ **Applies** the interdependency and interrelationship in the biotic and abiotic factors of the environment to promote conservation of the environment.

## CLASS X - SCIENCE

### Learner

- ❖ **Differentiates** materials/ objects/ organisms/ phenomena/ processes based on properties/ characteristics.
- ❖ **Classifies** materials/ objects/ organisms/ phenomena/ processes based on properties/ characteristics.
- ❖ **Plans and conducts** investigations/ experiments to arrive at and verify the facts, principles, phenomena or to seek answers to queries on their own.
- ❖ **Relates processes** and phenomena with causes/ effects.
- ❖ **Explains processes** and phenomena.
- ❖ **Draws labelled diagrams/** flow charts/ concept map/graphs.
- ❖ **Analyses and interprets** data/ graph/ figure.
- ❖ **Calculates** using the data given.
- ❖ **Uses scientific conventions** to represent units of various quantities/ symbols/ formulae/ equations.
- ❖ **Measures** physical quantities using appropriate apparatus/ instruments /devices.
- ❖ **Applies learning** to hypothetical situations.
- ❖ **Applies scientific concepts** in daily life and solving problems.
- ❖ **Derives formulae/** equations/ laws.
- ❖ **Draws conclusions.**
- ❖ **Takes initiative** to know about scientific discoveries/ inventions.
- ❖ **Exhibits creativity** in designing models using eco-friendly resources.
- ❖ **Exhibits values** of honesty/ objectivity/ rational thinking/ freedom from myth/ superstitious beliefs while taking decisions, respect for life etc.
- ❖ **Communicates** the findings and conclusions effectively.
- ❖ **Makes efforts to conserve the environment** realizing the inter-dependency and interrelationship in the biotic and abiotic factors of the environment

*(Source: Draft on Learning outcomes at the Secondary Stage, NCERT)*

### 1.5 Present status of Science Learning

Science Education in India is confronted with three major issues:

- ❖ It is still far from achieving the goal of equity enshrined in our Constitution.
- ❖ Even at its best, it develops competence but does not encourage inventiveness and creativity.
- ❖ The overpowering examination system is basic to most of the fundamental problems.



### NCERT (National Assessment Survey) Results:

The NAS surveyed a representative sample of all Government and Government -aided schools in each state and measured students' performance in five subjects - Mathematics, Science, Social Science, English and Modern Indian Languages (MIL) - Reading Comprehension, throughout the country on November 13, 2017. The learning levels of over 2.2 million students from 1,20,000 schools across 701 districts in all 36 States/UTs were assessed. The findings of the survey, are expected to help guide education policy, planning and implementation at national, state, district and classroom levels for improving learning levels of children and bringing about qualitative improvements.

According to the survey, in schools affiliated to the Central Board of Secondary Education (CBSE), the average score of a student was 51.10% in science.

### Analysis as per NAS- Class X -Cycle 2 (2017-18)

#### A. Skill-wise performance: (ITEM % CORRECT)

Subject	Skill 1 (% Correct)	Skill 2 (% Correct)	Skill 3 (% Correct)
Science	56	51	48

**Skill 1: Remembering:** Recognizing or recalling knowledge from memory.

**Skill 2: Understanding:** Constructing meaning from different types of functions be they written or graphic messages.

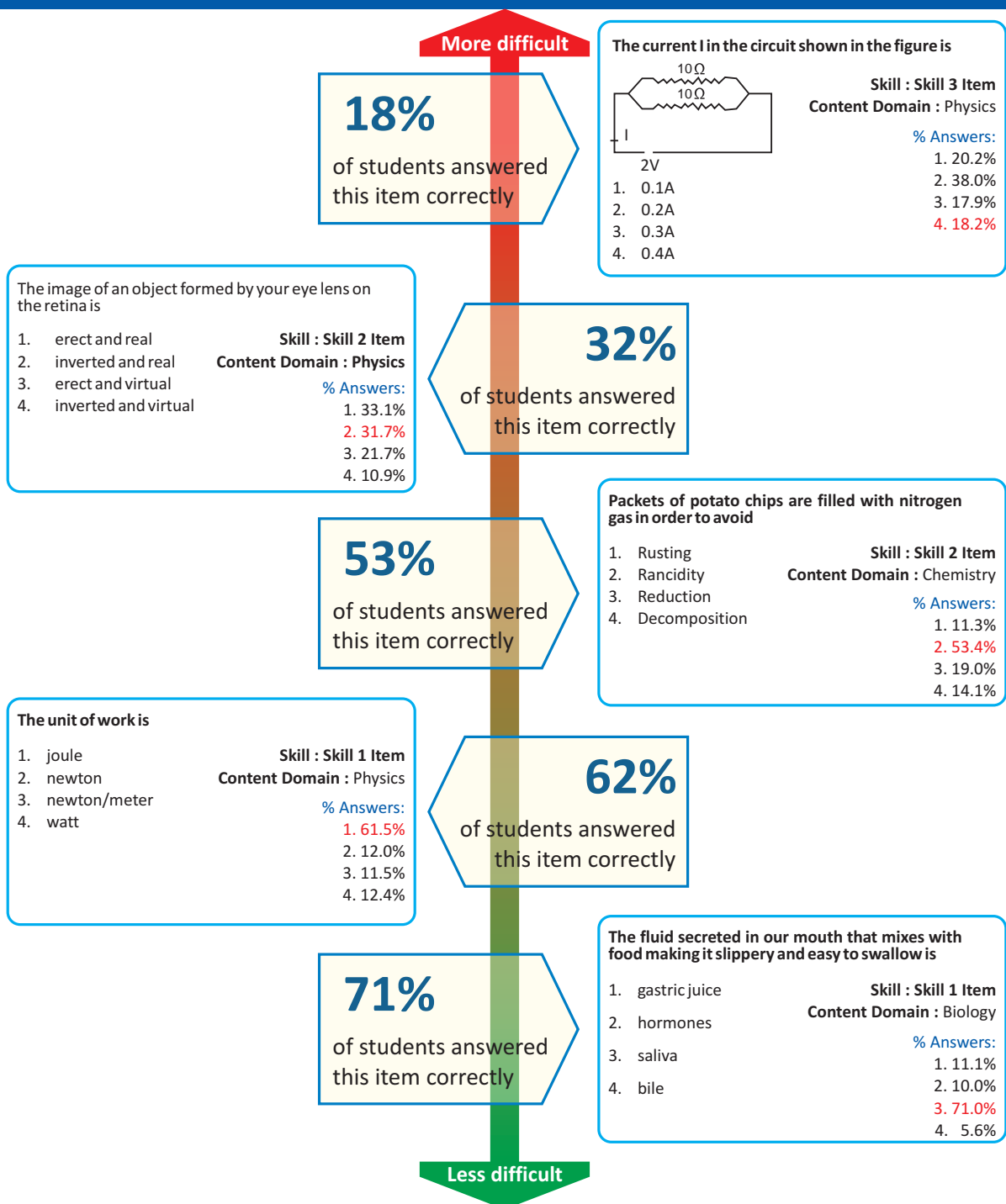
**Skill 3: Applying:** Carrying out or using a procedure through executing, or implementing.

#### B. Overall- Content Wise Performance:

SUBJECT	CONTENT DOMAIN	CBSE AVERAGE	NATIONAL AVERAGE
SCIENCE	FOOD	50	35
	MATERIALS	53	33
	THE LIVING WORLD	54	38
	MOVING THINGS, PEOPLE AND IDEAS	46	35
	HOW THINGS WORK	31	22
	NATURAL PHENOMENA	46	27
	NATURAL RESOURCES	56	40
	OVERALL	51	34

## C. Sample Questions and Percentage of Students that Answered Correctly

What students know and can do: **SCIENCE** (Performance of the students at the National level)



KEY

NAS item

This ladder shows the percentage of students answering selected NAS items correctly. It provides a snapshot of what students know and can do in Science.

It is evident from the above data that students have performed better in the questions that are based purely on remembering. The curricular expectations as defined by the NCERT are therefore not being met in most of the cases. Though the performance of students in the CBSE affiliated schools is above the national average, intensive efforts have to be made to improve the learning outcomes.



**“Making science relevant’ should not be something that the teacher does alone, but rather something that students learn to do, becoming progressively better at it through concerted practice.”**

**— NOAH FEINSTEIN, SALVAGING SCIENCE LITERACY, 2011**

### **1.6 Why must Scientific Literacy be Cultivated?**

One question that each Science teacher needs to ask is - 'What should my students know about science by the time they graduate from school?'

They should certainly be scientifically literate, to be able to participate in social activities.

Scientifically literate students have a set of basic skills that allow them to:

- **Access** the scientific information they need when confronting a real-world problem or question;
- **Critique** claims that utilize scientific evidence and reconcile conflicting claims about scientific evidence;
- **Understand** human factors that influence the creation, interpretation, and communication of scientific evidence; and
- **Integrate** thinking scientifically about a question with knowledge from other fields.

Retrieved from: <http://scienceliteracy.bard.edu>

Teachers' pedagogical strategies must center around hands-on, realistic, problem-solving situations.

We need to give students repeated opportunities to:

- Respond to real-world problems.
- Explore solutions to problems about which there is conflicting scientific evidence.
- Practice transferring their skills and knowledge from one context to another.

If students can transfer skills and knowledge from one context to another in the classroom, they will certainly be able to replicate this challenge outside the boundaries of the classroom in the real-world situations.

### **1.7 What Needs to be Done?**

In order to effect a qualitative change, a paradigm shift is needed vis-a vis Science Education in schools.

#### **Some Suggestions from NCF 2005:**

- ❖ Rote learning be discouraged.
- ❖ Inquiry skills be supported and strengthened by language, design and quantitative skills.
- ❖ Greater emphasis on activities aimed at stimulating investigative ability, inventiveness, and creativity.
- ❖ Participation in Science and Technology Fairs to be encouraged.
- ❖ Teacher Empowerment.



**Objectives of this handbook:**

The handbook gives an overview of Scientific Literacy with a special focus on PISA with reference to the content, process and context involved therein. It is expected that teachers will make use of this handbook for assessment to be integrated into the classroom transactions. Transactional strategies including *Assessment for Learning* are discussed in detail with a special emphasis on connecting Science to daily life.

We are committed to prepare students to lead productive and successful lives once they enter into the realm of adulthood. Two decades ago, educators did not anticipate what lay ahead for their students in the future. Yet, they tried to do their best to prepare their students for this world. Today, educators are still charged with the same complex task – preparing students for the unknown.

We hope this handbook will help in giving direction to the teachers to improve the competencies of children in Science so they can face the challenges of day-to-day life in the 21<sup>st</sup> Century.





## CHAPTER 2

# INTRODUCTION TO PISA



### 2.1 What is PISA

The Programme for International Student Assessment (PISA), a **project of member countries of the OECD** (Organization for Economic Co-operation and Development), is a **triennial international assessment** that **aims to evaluate education systems worldwide** by testing the skills and knowledge of 15-year-old students who have completed the end of their compulsory education. PISA is designed to assess how well they can apply what they learn in school to real-life situations. Over 90 countries have participated in the assessment so far, which has taken place at three year intervals since 2000.

#### Background

- PISA—Cabinet approval on 28 Jan'19 for signing MOU between MHRD & OECD for India's participation in PISA.
- Schools run by KVS, NVS & schools in UT of Chandigarh will participate.
- The test items shall be contextualized to Indian milieu.

### 2.2 Why PISA ?

PISA, a competency-based assessment, has been designed to assist governments in monitoring the outcomes of education systems in terms of student achievement on a regular basis and within an internationally accepted common framework. In other words, it will allow them to compare how students in their countries are performing on a set of common tasks compared to students in other countries. In this way, PISA helps governments to not only understand, but also to enhance, the effectiveness of their educational systems and to learn from other countries' practices. It can help policymakers use the results of PISA to make decisions about education, inform teaching and set new targets.

#### Why PISA for India?

- PISA—will help move towards competency based examination reforms in the school system.
- Will discourage rote learning.
- Lead to recognition and acceptability of Indian students & prepare them for the global economy of 21<sup>st</sup> Century.

Given the rapid pace with which changes are happening around us, we need our education to prepare us for the times to come. **Critical Thinking, Problem Solving, and Conceptual understanding** must become the key parameters of learning. The relevance of information is losing value but the ways and means of processing that information are progressively becoming more relevant.

Our current education system leaves our children far behind in all these aspects and in that light, PISA is a welcome change. We need to look at PISA as an intervention that will not only make our education more relevant for current times but also make it **future ready**. Activities and concepts in the classrooms need to engage the mind, inspire, and become contextual. Evaluation needs to be re-modeled to incorporate similar thinking. In that light PISA is a very welcome intervention both for the educators and the learners.

### 2.3 PISA Procedure

Every three years, students complete an assessment that includes items testing **Reading Literacy, Mathematical Literacy, and Scientific Literacy**. In each cycle of PISA, **one of the cognitive areas is the main focus of assessment, with most of the items focusing on this area and fewer items on the other**



**two areas.** In addition to these students were tested in an innovative domain such as collaborative problem solving in 2015 and global competence in 2018. **Students** also complete an **extensive background questionnaire**, and school. Principals complete

a **survey describing the context of education** at their school, including the level of resources in the school, qualifications of staff and teacher morale. The data collected from the assessment and background questionnaires are analyzed and the results are published a year after the assessment. These studies enable the participating countries to benchmark their students against similar samples of students from other countries.

#### The Indian Plan for PISA

- CBSE & NCERT -- part of the process & activities leading to the actual test.
- Field Trial(FT) --to be conducted in April 2020.
- For FT, 25 schools x 36 students each = 900 students to be assessed
- PISA 2021 --officially called Main Survey--to be conducted in April 2021.

## 2.4 PISA 2021

- **India shall be participating for the second time, the first being in 2009.**
- **36 OECD member countries and over 50 non-members are expected to participate.**
- **Each student, selected on the basis of random sampling, will be tested on any two out of the three domains, viz. Reading Literacy, Mathematical Literacy and Scientific Literacy.**

#### PISA 2021

5250 students (150 schools x 35 students) will be assessed on the following subjects in the paper-based assessment

- Mathematics and Science (33% students)
- Mathematics and Reading (33% students)
- Reading and Science (33% students)

#### Assessment Goals:

- ✓ To evaluate outcomes of learning.
- ✓ To assess how well students can apply what they learn in school to real-life situations.
- ✓ To show what 15-year-olds have learnt inside and outside a classroom.
- ✓ To measure literacy in terms of knowledge, skills and competencies.

#### The report of the findings from PISA focuses on issues such as:

- ✓ How well are young adults prepared to meet the challenges of the future?
- ✓ Can they analyze, reason and communicate their ideas effectively?
- ✓ What skills do they possess that will facilitate their capacity to adapt to rapid societal change?
- ✓ Are some ways of organizing schools or school learning more effective than others?
- ✓ How does the quality of school resources influence student outcomes?
- ✓ What educational structures and practices maximize the opportunities of students from disadvantaged backgrounds?
- ✓ How equitable is the provision of education within a country or across countries?



## 2.5 Principles of Testing in PISA

### PISA consists of the following:

#### I. Paper and pen assessment

- **Cognitive Assessment**--covers three domains: **Reading Literacy, Mathematical Literacy & Scientific Literacy.**
- The assessment of cross-curriculum competencies is an integral part of PISA.
- Emphasis is placed on the mastery of processes, the understanding of concepts and the ability to function in various situations within each domain.
- Thus, PISA test is different:
  - Focus is on understanding
  - Proper reading abilities are required
  - No guesswork is the thumb rule
  - Answers to one test item may be related to previous answers
- Participating students complete a **two-hour paper and-pen assessment.**

#### II. Context questionnaire

To gather contextual information, PISA asks students and the principals of their schools to respond to questionnaires. These take about 35 and 45 minutes, respectively, to complete.

The questionnaires seek information about:

- Students and their family backgrounds, including their economic, social and cultural capital.
- Aspects of students' lives, such as their attitudes towards learning, their habits and life in and outsidess of schools and their family environment.
- Aspects of schools, such as the quality of the schools' human and material resources, public and private management and funding, decision-making processes, staffing practices and the school's curricular emphasis and extracurricular activities offered.
- Context of instruction, including institutional structures and types, class size, classroom and school climate and science activities in class.
- Aspects of learning, including students' interest, motivation and engagement.

#### Target Group

- Children of age group 15 years 3 months - 16 years 2 months attending any educational institution in the country (selected region), including public, private, aided, international schools.
- Open School students are not eligible.
- PISA will be held in April 2021 and the target group will be students born between January 2005 to February 2006.



## 2.6 The Challenge Ahead

- 2021--PISA will help reveal where India stands globally as far as learning outcomes are concerned.
- The participation in PISA 2021 would indicate the health of the education system and would motivate other states in the subsequent cycles. This will lead to an improvement in the learning levels of the children and enhance the quality of education in the country.
- The challenge before the teaching community is to collaborate, train and brace our students for PISA 2021.



## CHAPTER 3

# SCIENTIFIC LITERACY IN PISA



An understanding of Science and Technology is central to a young person's preparedness for life in modern society, in which science and technology play a significant role. This understanding also empowers individuals to understand public policy where issues of science and technology impact their lives.

### 3.1 What is Scientific Literacy?

**Scientific Literacy** - *“The capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.”*

**Scientific literacy means that a person:**

- ✓ can ask, find, or determine answers to questions derived from curiosity about everyday experiences.
- ✓ has the ability to describe, explain, and predict natural phenomena.
- ✓ is able to read with understanding, articles about science in the popular press and to engage in social conversation about the validity of the conclusions.
- ✓ can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed.
- ✓ is able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it.
- ✓ has the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

(National Science Education Standards, page 22)

### 3.2. How is Scientific Literacy defined in PISA?

The PISA Scientific Literacy definition includes:

- **Knowledge of Science**--refers to the knowledge of the natural world across the major fields of physics, chemistry, biological science, earth and space science, and science-based technology.
- **Knowledge about Science**-- refers to the knowledge of the means (scientific inquiry) and the goals (scientific explanations) of science.



PISA believes that every individual should be able to think scientifically about the evidence they encounter in their real-life challenges.

Students are required to use the knowledge that would be gained from the science curriculum and apply it in novel and real-life situations.

### The 2015 PISA Definition of Scientific Literacy

The ability to engage with science-related issues with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires certain **competencies** (as given below in Figure 1).

**Explain phenomena scientifically:** Recognize, offer and evaluate explanations for a range of natural and technological phenomena demonstrating the ability to

- Recall and apply appropriate scientific knowledge
- Identify, use and generate explanatory models and representations
- Make and justify appropriate predictions
- Offer explanatory hypotheses
- Explain the potential implications of scientific knowledge for society

**Interpret data and evidence scientifically:** Analyze and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions demonstrating the ability to

- Transform data from one representation to another
- Analyze and interpret data and draw appropriate conclusions
- Identify the assumptions, evidence and reasoning in science related texts
- Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations
- Evaluate scientific arguments and evidence from different sources (e.g. newspapers, journals, internet etc.)

**Evaluate and design scientific inquiry:** Describe and appraise scientific investigations and propose ways of addressing questions scientifically demonstrating the ability to

- Identify the question explored in a given scientific study
- Distinguish questions that are possible to investigate scientifically
- Propose a way of exploring a given question scientifically
- Evaluate ways of exploring a given question scientifically
- Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalisability of explanations

Figure 1: Essential Features of each of the Three Competencies

### 3.3. How is Scientific Literacy measured in PISA?

The scientific literacy framework comprises four interrelated aspects:

- the **contexts** in which tasks are embedded
- the **competencies** that students need to apply
- the **knowledge domains** involved and
- **students' attitudes** towards science

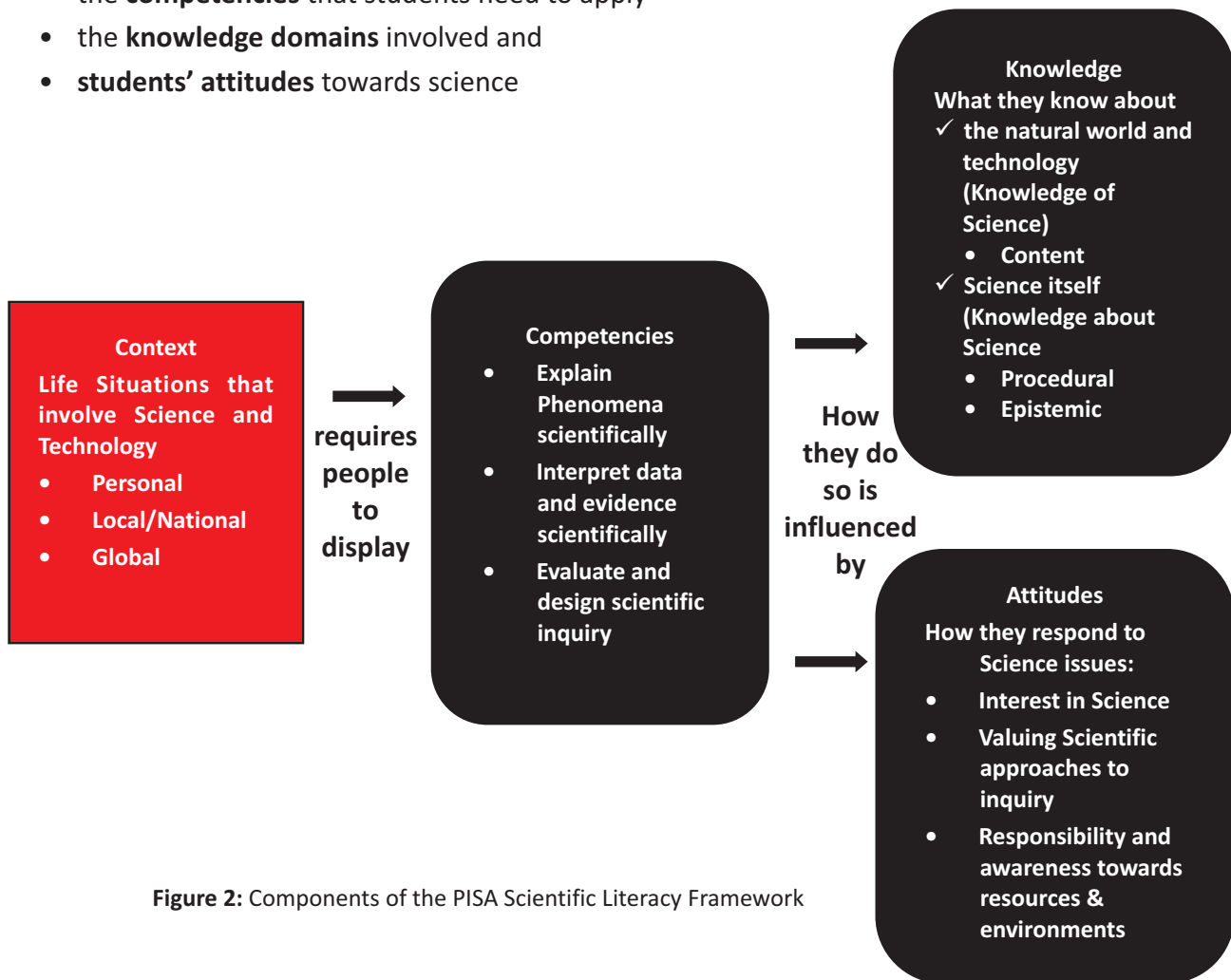


Figure 2: Components of the PISA Scientific Literacy Framework

#### Situations and Context

PISA's orientation focuses on preparing students for their future lives. That is the reason why the test **items for the PISA science assessment are situated in general life** and not just life in the classroom. In the PISA scientific literacy assessment, the focus of the items is on:

- situations relating to the self, family and peer groups (*personal*)
- to the community (*social*) and
- to life across the world (*global*)

Some items are framed in a historical situation, in which an understanding of the advances in scientific knowledge can be assessed.

**Figure 3** lists the applications of science, within **personal, social and global** situations, which are primarily **used as the contexts** for the PISA assessment. These are not definitive: other situations, such as *technical* and *historical* and other areas of application are also used in PISA. The areas of application are: **health, natural resources, the environment, hazards and the frontiers of science and technology**



Criteria	<b>Personal</b> Self, family and peer groups	<b>Social</b> The community local/national	<b>Global</b> Life across the world
<b>Health</b>	Maintenance of health, accidents, nutrition	Control of diseases, transmissions, food choices, community health	Epidemics, spread of infectious diseases
<b>Natural Resources</b>	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non renewable energy sources, natural systems, population growth, sustainable uses of resources.
<b>Environment Quality</b>	Environmentally friendly behaviour, use and disposal of materials	Population distribution, disposal of waste, environmental impact, local weather	Biodiversity, ecological sustainability, control of pollution, production and loss of soil
<b>Hazards</b>	Natural and human-induced decisions about housing	Rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment	Climate change, impact of modern communication
<b>Frontiers of Science &amp; Technology</b>	Interest in science's explanations of natural phenomena, science-based hobbies, sports and leisure, music and personal technology	New materials, devices and processes, genetic modifications, health technology, transport	Extinction of species, exploration of space, origin and structure of the Universe

Figure 3: Contexts for PISA Scientific Literacy Assessment

### 3.4. Scientific Competencies

The PISA scientific literacy assessment items require students to **identify scientifically oriented issues, explain phenomena scientifically, and use scientific evidence**. These three competencies were chosen because of their importance to the practice of science and their connection to key cognitive abilities such as **inductive and deductive reasoning, systems-based thinking, critical decision-making, transformation of information** (eg. creating tables or graphs out of raw data), and thinking in terms of models and use of science.







## Scientific Knowledge.

It refers both to the Knowledge of Science (knowledge about the natural world) and the Knowledge about Science itself.

### Knowledge of Science

Only a sample of students' knowledge of science can be assessed in any one PISA assessment, and the focus of the assessment is the extent to which students apply their knowledge in contexts of relevance to their lives. The assessed knowledge could be selected from the major fields of physics, chemistry, biology, earth and space science, and technology according to the following criteria. Test Items have to be:

- relevant to real-life situations. Scientific knowledge differs in the degree to which it is useful to the life of individuals;
- representative of important scientific concepts and thus have enduring utility; and
- appropriate to the developmental level of 15-year-old students.

#### I. Physical systems

- Structure of matter (e.g. particle models, bonds)
- Properties of matter (e.g. changes of state, thermal and electrical conductivity)
- Chemical changes of matter (e.g. reactions, energy transfer, acids/bases)
- Motions and forces (e.g. velocity, friction)
- Energy and its transformation (e.g. conservation, dissipation, chemical reactions)
- Interactions of energy and matter (e.g. light and radio waves, sound and seismic waves)

#### II. Living systems

- Cells (e.g. structures and functions, DNA, plant, animal)
- Humans (e.g. health, nutrition, subsystems [ie. digestion, respiration, circulation, excretion, and their relationships], diseases, reproduction)
- Populations (e.g. species, evolution, biodiversity, genetic variation)
- Ecosystems (e.g. food chains, matter, energy flow), Biosphere (e.g. ecosystem services, sustainability)
- Biosphere (e.g. ecosystem services, sustainability)

#### III. Earth and space systems

- Structures of Earth systems (e.g. lithosphere, atmosphere, hydrosphere)
- Energy in Earth systems (e.g. sources, global climate)
- Change in Earth systems (e.g. plate tectonics, geochemical cycles, constructive and destructive forces)
- Earth's history (e.g. fossils, origin and evolution)
- Earth in space (e.g. gravity, solar systems)

#### IV. Technology systems

- Role of science-based technology (e.g. solve problems, help humans meet needs and wants, design and conduct investigations)
- Relationships between science and technology (e.g. technologies contribute to scientific advancement)
- Concepts (e.g. optimization, trade-offs, cost, risk, benefit)
- Important principles (e.g. criteria, constraints, innovation, invention, problem solving)

Figure 4: The four Content Areas defined within the *Knowledge of Science*



### 3.5. Knowledge about Science

In addition to *Knowledge of Science*, PISA assesses **Knowledge About Science**, for which the framework for scientific literacy defines two categories: The first of these is '**Scientific Inquiry**', which centres on inquiry as the central process of science and the various components of that process. The second is '**Scientific Explanations**', which are the result of scientific inquiry.

**Inquiry** can be thought of as the means of science – how scientists obtain evidence – and explanations as to the goals of science – how scientists use data.

The examples shown in **Figure 5** convey the general meanings of the two categories:

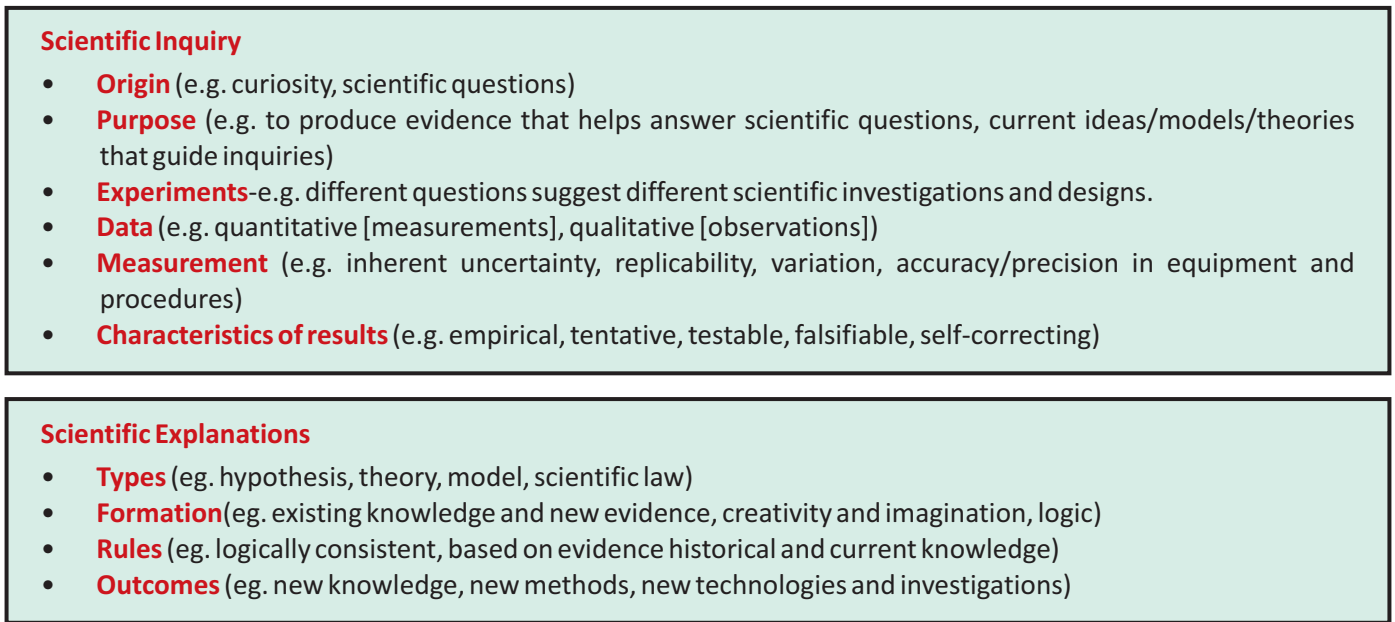


Figure 5: PISA categories of Knowledge about Science

### 3.6. Scientific Literacy Framework

A framework for mapping items against the two dimensions of knowledge and competencies. Each item can also be mapped using a third dimension based on a depth of knowledge (DoK) taxonomy.

	Competencies			DOK			
		Explain Phenomena scientifically	Evaluate and design scientific inquiry	Interpret data and evidence scientifically	Low	Medium	High
Knowledge	Content Knowledge						
	Procedural Knowledge						
	Epistemic Knowledge						

Figure 6: Scientific Literacy Framework



## Scientific Literacy—Levels

### Levels – Depth of Knowledge (DoK) Taxonomy

#### Low (L)

Carrying out a one-step procedure, for example, recall of a fact, term, principle or concept or locating a single point of information from a graph or table. .

#### Medium (M)

Use and application of conceptual knowledge to describe or explain phenomena, select appropriate procedures involving two or more steps, organize/display data, interpret or use simple data sets or graphs.

#### High (H)

Analyze complex information or data, synthesize or evaluate evidence, justify, reason amongst the various given sources, develop a plan or sequence of steps to approach a problem.

### 3.7 Scientific Literacy - Format of Assessment

- Students are presented with units that require them to construct a response to a stimulus and a series of questions (or “items”).
- Context is represented in each unit by the stimulus material, which is typically a brief written passage or text accompanying a table, chart, graph, photograph or diagram. Each unit contains several questions or items.
- While students need to possess **a certain level of reading competency** to understand and answer the science items, the stimulus material uses language that is clear, simple and brief as possible to convey the appropriate meaning.
- More importantly, the items require students to use one or more of the scientific competencies as well as knowledge of science and/or knowledge about science.

#### Type of Items

Three types of items are generally used to assess the competencies and scientific knowledge identified in the framework:

- **Simple multiple-choice items-** items calling for the selection of a single response from four options, the selection of a “hot spot”, an answer that is a selectable element within a graphic or text.
- **Complex multiple-choice items-** items calling for responses to a series of related “Yes/No” questions that are treated for scoring as a single item – selection of more than one response from a list
- **Constructed-response items-** (Open and Closed) -- items calling for written or drawn responses. Constructed- response items in scientific literacy typically call for a written response ranging from a phrase to a short paragraph (e.g. two to four sentences of explanation). A small number of constructed-response items call for drawing (e.g. a graph or diagram).

Besides, **Binary Choice** questions are also asked.

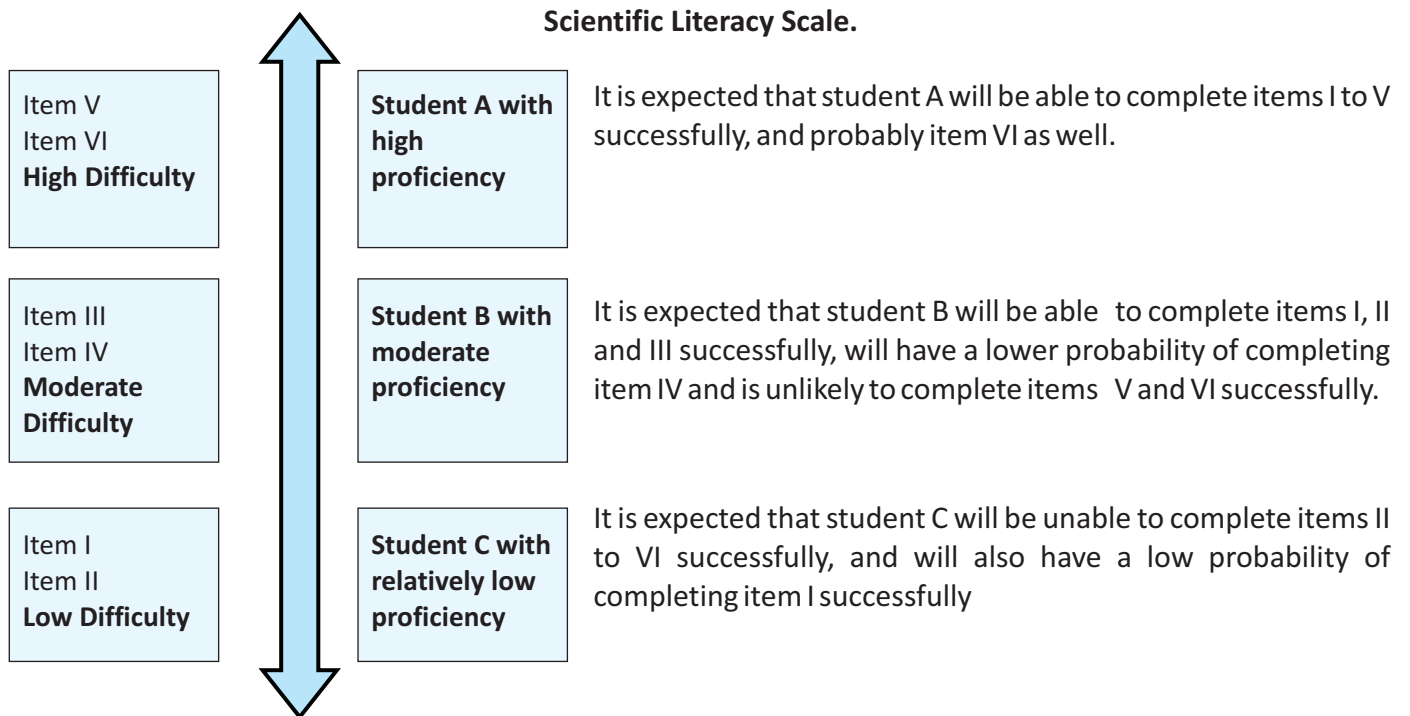
### 3.8. Scaling the Scientific Literacy tasks

The scale of scientific literacy is constructed using Item Response Theory, with scientific literacy items ranked by difficulty and linked to student proficiency. Using such methods means that the relative ability of students taking a particular test can be estimated by considering the proportion of test items they answer correctly, while the relative difficulty of items in a test can be estimated by considering the proportion of students getting each item correct. On this scale, it is possible to estimate the location of individual students, and to describe the degree of scientific literacy that they possess.

The estimate of student proficiency reflects the kind of tasks he/she would be expected to complete successfully . A student whose ability places him/her at a certain point on the PISA scientific literacy scale



would most likely be able to successfully complete tasks at or below that location, and increasingly more likely to complete tasks located at progressively lower points on the scale, but would be less likely to be able to complete tasks above that point, and increasingly less likely to complete tasks located at progressively higher points on the scale.



**Figure 7:** Relationship Between Items and Students on the Scientific Literacy Scale

### 3.9. Suggestions for Teaching

- ❖ Engage your students in each task given in the document as a whole-class discussion or ask them to attempt a task and then discuss it with them.
- ❖ Scoring criteria used by the PISA markers to score the actual assessment are provided. Examine the criteria and review the acceptable answers with your students.
- ❖ Use the tasks when planning a unit of work on a specific topic in the curriculum. Try to incorporate the tasks into your instructional and assessment plans.
- ❖ Remind students that partial marks are given for partially correct answers and encourage them to take the assessment seriously and strive for excellence.
- ❖ Discussion on incorrect answers can open up new areas for conceptual understanding.

PISA believes that every individual should be able to think scientifically about the evidences they encounter in their real-life challenges. The PISA assessment, therefore, tests students' performance in applying scientific literacy in real-life situations. Students should be able to use scientific processes, scientific concepts, and scientific knowledge to answer questions and make decisions about the natural world. The student is required to use the knowledge that would be gained from the science curriculum and apply it in a novel situation.



## CHAPTER 4

# EFFECTIVE TRANSACTIONAL STRATEGIES FOR THE TEACHING OF SCIENCE



*“True teachers are those who use themselves as bridges over which they invite their students to cross; then, having facilitated their crossing, joyfully collapse, encouraging them to create their own.” — Nikos Kazantzakis*

A significant pre-requisite to developing the higher-order problem - solving, critical thinking and creative thinking skills is to ensure that students gain mastery over the Content Knowledge right at the outset. The content should be relevant and contextualized. Ensuring content mastery would build a firm foundation on which the edifice of critical and creative thinking can be seamlessly built.

Teachers can study the table given below and identify the approach to teaching being followed by them. Is it a mere retrieval of information that we are targeting in the Science classes or are we developing the higher-order thinking skills of our students?

	<b>Traditional Approach</b>	<b>Modern Approach</b>
Principle Learning Theory	Behaviorism	Constructivism
Student Participation	Passive	Active
Student Involvement in Outcomes	Decreased Responsibility	Increased Responsibility
Student Role	Direction Follower	Problem Solver
Curriculum Goals	Product Oriented	Process Oriented
Teacher's Role	Director/Transmitter	Guide/Facilitator

**Figure 8:** Comparison of Modern Instructional Approach and Traditional Instructional Approaches

### **A question that all teachers need to answer for themselves -**

Do I need to change my approach to teaching to prepare my students for life and to empower them to confront challenging experiences?

**Instructional Practices** have a significant effect not only on students' performance but also on their attitude towards Science. The way teachers transact in the classroom has the potential to either engage students with science or alienate them from it. This, in turn, highlights the need to identify and adopt the core teaching practices that have a positive impact.



Science teaching should be ideally practicing **Science in Action**. For this we need to:

- ✓ Teach scientific ways of thinking.
- ✓ Actively involve students in their learning.
- ✓ Help students to develop a conceptual framework as well as to develop problem solving skills.
- ✓ Promote student discussion and group activities.
- ✓ Help students experience science in varied, interesting, and enjoyable ways.
- ✓ Assess student understanding at frequent intervals throughout the learning process.

#### 4.1 Spiral Learning

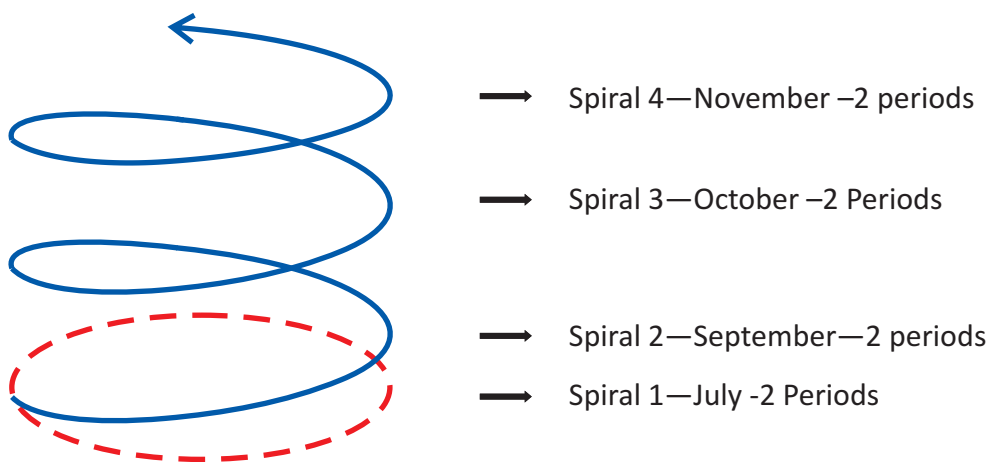
A method based on the premise that a student learns more about a subject each time the topic is reviewed or encountered as it expands their knowledge and improves their skills.

The basic idea behind the spiral progression approach is to expose the learners to a wide variety of concepts/topics, skills and attitudes that are deemed of continual concern to everyone until they are mastered. A spiral curriculum design is one in which key concepts are presented repeatedly throughout the curriculum but with deepening layers of complexity.

After mastery of the initial topic, the student spirals upwards as the new knowledge is introduced in next lessons, enabling him/her to reinforce what is already learned. A rich breadth and depth of knowledge is, thus achieved. The previously learned concept is reviewed hence improving its retention. The topic may be progressively elaborated when it is reintroduced, leading to a broadened understanding and transfer of learning.

By the final round of spiral learning, students become more participative. The teacher can design a game, a puzzle, or a task that spans the major milestones expected to have been achieved. The responses of students can help teachers to assess their learning levels.

Our NCERT curriculum design is also spiral. For example, the concept of light is introduced in Class VI, VII, VIII, X and XII but in varying and increasing order of complexity. Given below is an example of how to use the spiral method of teaching for one concept in a particular class.





**Example: Spiral Learning**  
**Chapter: Reflection and Refraction of Light**  
**Class: X**

**Spiral 1—July (2 Periods)—Overview 'Reflection of Light'**

- i. Spherical Mirrors
- ii. Image Formation by Spherical Mirrors--Rules
- iii. Sign Convention

**Spiral 2—September (2 Periods)—Overview 'Refraction of Light'**

- i. Refraction through glass slab and prism
- ii. Image formation through lenses
- iii. Sign Convention

**Spiral 3—October (2 Periods)**

- i. Reflection of light : image-formation diagrams
- ii. Formula and Numericals

**Spiral 4—November (2 Periods)**

- i. Refraction of Light—the image diagrams of lenses
- ii. Lens Formula and Numericals

A few teaching strategies that centre around this concept are given along with examples.

**4.2 Experiential Learning**

In its simplest form, **experiential learning** means learning from experience or learning by doing. Experiential education first immerses learners in an experience and then encourages reflection about the experience to develop new skills, new attitudes, or new ways of thinking.

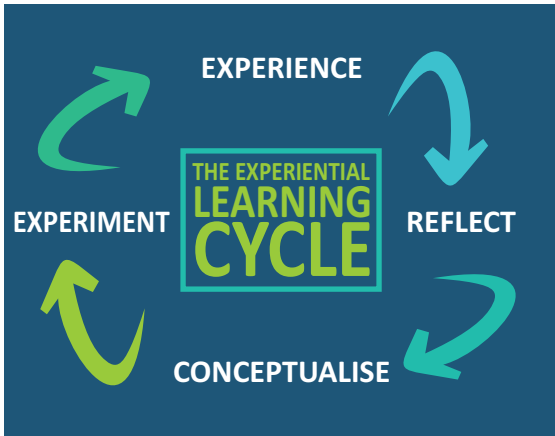
There are a wide range of design models that aim to embed learning within real-world contexts, including laboratory work, problem-based learning, project-based learning, inquiry-based learning, cooperative (work or community based) learning.

Experiential Learning focuses on learners reflecting on their experience of doing something to gain conceptual insight as well as practical expertise. Kolb's experiential learning model suggests four stages in this process:

- Active Experimentation
- Concrete Experience
- Reflective Observation
- Abstract Conceptualization

**Key things to remember for experiential learning classroom activities**

- ❖ **Being able to make mistakes:** Teachers must overcome the stigma attached to students' mistakes by actively celebrating them as opportunities for learning.
- ❖ **Personal Relevance:** Discover what the students are interested in, and then select the appropriate problems.
- ❖ **Understand why they are doing something:** This is important for students to be truly involved, else they may not learn anything at all.
- ❖ **Matching students with appropriate activities:** In experiential learning, the means are as important as the ends. Students must stay engaged throughout the whole process. Not enough challenge may result in boredom, and too much challenge may result in frustration.
- ❖ **Reflecting on their experience:** Reflection, along with driving questions from the teacher will help students maintain interest, learn successfully and complete tasks.
- ❖ **Delegating authority to the students:** The teacher serves as a guide and a resource to students, rather than an authority figure.



Picture courtesy: growthengineering.co.uk

**Experiential learning activities can help students:**

- **Remain focused**-Students who are engaged and learning actively are less likely to become bored and disinterested.
- **Learn differently**-When students are involved in the learning process they are engaged emotionally and experience learning in a dynamic way.
- **Learn faster**-Learning first hand requires intensive problem-solving and critical thinking. These processes boost student engagement, accelerate learning and improve content retention.

### Example : Experiential learning

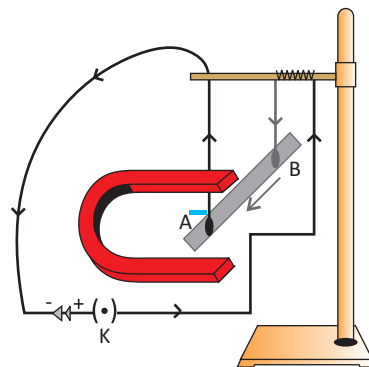
**Class:** X

**Unit:** Magnetic Effects of Electric Current

**Objective:** To find the relation between the magnetic field and the force acting on the current-carrying conductor

**Activity:** Force acting on a current-carrying conductor kept in a magnetic field

1. Arrange the experimental set up as shown in the figure



Picture courtesy: NCERT Class X Science text book

2. Observe what happens when current is passed through the rod from B to A (Rod gets displaced).
3. Observe the direction of motion of the rod (towards left).
4. Reverse the direction of current through the rod.
5. Notice the direction in which the rod moves.

**Let students draw conclusions:**

- a. Force acts on a current-carrying conductor.
- b. The direction of motion of the conductor depends on the direction of the conductor.





**Students may extend the experiment to investigate the impact of additional parameters.**

(Impact of increasing the magnetic field, strength of the current, length of the wire etc.)

- Students use their previous knowledge/schema as the basis on which the new experience is built. The students are active, responsible and motivated.
- Laboratory experiences enhance students' understanding of scientific facts and concepts.
- As a result of laboratory experiences that make science 'come alive,' students become interested in learning more about science.
- ❖ Please note that you can learn more about Experiential Learning from the ***Handbook on Experiential Learning by CBSE.***

### 4.3 Cooperative Learning

Cooperative Learning involves structuring classes around small groups that work together in such a way that each group member's success is dependent on the group success.

#### Features of Cooperative Learning

- Small-group learning: Small groups of students work together on a common task.
- Positive interdependence: Students feel responsible for their own and the group efforts.
- Face-to-face interaction: Students encourage and support one another; the environment encourages discussion.
- Individual and group accountability: Each student is responsible for doing their part; the group is accountable for meeting its goal.
- Group behaviours: Group members enhance interpersonal, social, and collaborative skills needed to work with others.

When implemented well, cooperative learning

- ✓ encourages active learning and achievement.
- ✓ leads to student discussion, confidence and motivation.
- ✓ develops interpersonal skills.
- ✓ gives them authentic experiences.

#### Example : Cooperative Learning Strategy

**Classes:** VI-VIII

**Unit:** Conservation of Energy

**Objective:** Sensitizing students towards energy conservation

**Activity:** Survey on energy consumption in school

1. Divide the students into small groups. Each group is assigned a specific task as listed below:
  - **Group 1**– Check how many tube lights/fans are installed and are functional/non-functional in the classrooms of each floor of the school building.
  - **Group 2**– Calculate the number of lights/fans installed and functional/non-functional in the corridors of each floor/ miscellaneous areas of the school, including the guardrooms.



- **Group 3**– Calculate the number of lights/fans installed and functional/non-functional in the laboratories and different departments of the school.
- **Group 4**– Calculate the number of computers, printers, interactive boards and other ICT related equipment in the school.
- **Group 5**– Check the number of ACs being used in all the rooms of the school.
- **Group 6**– Analyze the monthly electricity bill of the school and note the variations observed for a period of 5 months (June to November)

2. All the groups will collate the data, analyze their findings and interpret the energy consumption of the school in the given period.

3. A conclusion will be derived based on the data and an action plan will be devised

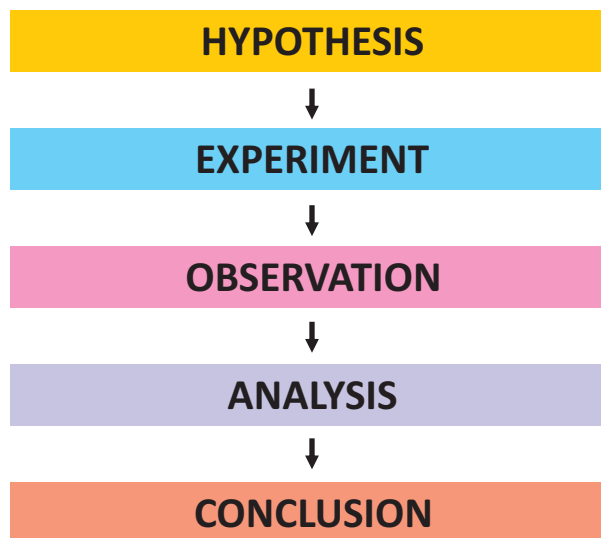
4. Students will be expected to represent the findings from the survey graphically (Histogram/Pie Chart/Line Graphs/Bar diagram).

This will help students collect and interpret data on a micro level and be prepared for the macro-level data interpretations. Students will familiarize themselves with the graphic representations which form part of PISA type test items.

#### 4.4 Experimentation

An experiment is an organized and detailed series of steps performed to validate or reject a hypothesis. Experiments help the students to see the theory in action, understand it with a much greater sense and make it easier to learn and remember.

Experiments are one of the key components of the scientific method, which is a set of procedures that scientists follow to gain knowledge about the world. The five main components of the scientific method are:



#### Why use Experiments?

- To introduce new ideas or clarify puzzling aspects of topics with which students typically struggle.
- If the result of an experiment is surprising yet convincing, students are in a position to build ownership of the new idea and use it to scaffold learning.
- The post-experiment assignments can push students to describe a follow-up experiment or to extend their conceptual understanding to another application.





### Example : Experimentation

<b>Classes:</b>	<b>VI-IX</b>
<b>Unit:</b>	<b>Chemical Reactions</b>
<b>Objective:</b>	<b>To provide hands-on experience and application of conceptual knowledge to real-life experiences</b>
<b>Activity:</b>	<b>The teacher will demonstrate Neutralization Reaction using acid and base as a Lab activity</b>
<b>Value Addition:</b>	<b>Neutralization in everyday life</b>

Students are expected to understand that neutralization helps in curing acidity in the stomach. Antacids (base) neutralize the effect of Hydrochloric acid (HCl) in the stomach when it reacts with excessive acid. Antacids are used for the treatment of gastric hyperactivity or ulcers.

#### 4.5 Encouraging Self-Experimentation

Self-efficacy as defined by Albert Bandura is one's belief in one's ability to succeed in specific situations or accomplish a task. Opportunities and activities for students to enhance their self-efficacy in the form of designing experiments and activities on their own helps to boost their confidence to approach tasks positively.

### Example : Self Experimentation /Learning by Doing

<b>Classes:</b>	<b>VI-IX</b>
<b>Unit:</b>	<b>Natural indicator, Refraction</b>
<b>Objective:</b>	<b>To provide self-driven, hands-on experience and application of conceptual knowledge to real-life experiences</b>
<b>Activity:</b>	<b>1. Test the acidic/basic nature of a given solution using hibiscus as a natural indicator 2. Observe the bending of light rays</b>

#### Activity 1:

- Students will prepare an indicator from hibiscus petals and test the acidic and basic behaviour of different substances/solutions viz. lemon juice, window cleaner, soap, vinegar, curd, etc.
- Students will categorize the above solutions into acids and bases on the basis of the change in the colour that they observe.





### Activity 2:

Students will observe the bending of light rays (refraction) through a straw dipped in a glass full of water.

Students can similarly observe the bending of light through a magnifying lens, oil, glycerine or kerosene and conclude their findings.



### Additional Suggested Activities for Students:

- Observe the reflection of light with the help of a comb and a mirror.
- Verify the laws of reflection of sound using cardboard rolls and alarm clock.
- Prepare an electric tester using wires, battery, bulb and safety pins.
- Prepare an electromagnet using a long nail and an electric wire.
- Prepare a model showing the working of the lungs using a bottle, straw and balloons.

## 4.6 Inquiry Based Learning

Through scientific inquiry, students should develop a critical way of engaging with science. They should be able to acquire a deep understanding of a topic, develop a coherent scientific method, and ultimately provide a robust answer to the question under investigation (Crawford, 2007). Thus, this strategy emphasizes the student's role in the learning process. Students are encouraged to explore the material, ask questions, and share ideas.

### Inquiry Based Learning helps to:

- ✓ **foster curiosity** in students.
- ✓ **enhancing capacities & students** to explain their ideas, argue and debate about science concepts.
- ✓ **strengthen students' understanding** of topics- they are made to think broadly regarding scientific concepts and their relevance to their own lives.
- ✓ **permits students to take ownership of their learning** – they do scientific study, conduct relevant research and discuss current scientific issues.

The **5E learning cycle** gives students a framework for learning .

- ❖ It starts with the teacher introducing an engaging experience. This can be anything from a relevant YouTube video to a class discussion.
- ❖ Students then explore the content through a lab experience. This exposes students to the content without specifically telling students the information.
- ❖ Next, the teacher explains the content through direct instruction. This can take the form of a PowerPoint lecture or class discussion.
- ❖ Finally, the teacher can introduce an extension exercise followed by an evaluation. The evaluation may be a formative or summative assessment.



## 5E MODEL OF INSTRUCTION

In this approach learners construct new ideas beyond their existing knowledge and ideas.

### 1. Engage

Students become mentally engaged and their interest is kindled in the concept, process, skill to be learned. They make connections between past and present learning experiences.

### 2. Explore

Students identify and develop concepts, processes, and skills through hands on activities, distinguish questions, develop a hypotheses and test variables.

### 3. Explain

Students get a chance to verbalize their conceptual understanding or to develop new skills or behaviours. Teachers also get a chance to introduce formal terms, definitions and provide explanations.

### 4. Extend

Implies extension of students' conceptual understanding. Through new learning and experiences, the learners develop broader understanding of major concepts, obtain more information about their areas of interest and refine their skills.

### 5. Evaluate

Students assess their understanding and teachers evaluate students' learning of key concepts and skill development through conversations, writing and demonstrations.

Figure 9: The Constructivist Approach to Learning - The 5E Model of Instruction



### Example : Inquiry Based Learning

**Class:** VI

**Unit:** Shadows

**Objective:** • to investigate the parameters that affect the formation of shadows, the factors that affect their size/formation on a screen.  
• to interpret observations in relation to the properties of light.

**Activity:** Making Students understand the concept of shadows

Step 1:	Ask students - What are shadows? Invite responses.	Engage
Step 2:	Ask students to discuss in groups-- how shadows are formed	Explore
Step 3:	Group leaders make presentations	Explain
Step 4:	Extension of the topic	Extend
	1. Are the shadows formed with all types of objects?	
	2. Does light travel in a straight line?	
	3. Is it possible to design an activity to show that light travels in a straight line?	
Step 5:	Other groups carry out peer evaluation	Evaluate

#### 4.7 Teaching through Technology

Information and Communication Technology plays a major role in human activities in everyday life to cope with and adapt to the demands of the environment. If the vision of science education is to bring socio-economic development, the role of ICT in science education cannot be overemphasized. Across the world, it is generally agreed that development could be more meaningful if and when it is science and technology-driven. Information and Communications Technology (ICT) can impact student learning when teachers are digitally literate and understand how to integrate it into the curriculum.

#### Why use ICT in the Teaching of Science ?

- Ensures a learner-centered and activity-oriented teaching/learning approach.
- Develops a deep understanding of the learning tools and concepts.
- Promotes students' intellectual development through higher-order thinking and problem-solving.
- Improves communication skills of students.
- Promotes an interactive teaching learning environment by broadening communication.
- Computer generated lesson helps to illustrate topics that cannot be presented effectively unidimensionally.

#### ICT removes problems concerning space and time

The students can contact the teacher and exchange information anywhere, anytime. In principle, the students can draw on a global pool of knowledge.

#### ICT makes serving and sharing knowledge easier

The students can individually and /or together create records, notes and presentations and thus, register their progress as well as share it with their peers.



### ICT provides global access to knowledge.

- ❖ Instant sharing of experience and best practices.
- ❖ Self-paced and self-based learning.
- ❖ Learning becomes interactive and joyful through multimedia tools.
- ❖ Simulations of experiential learning.
- ❖ Opening windows for new thinking, an atmosphere of innovation.
- ❖ Bringing excitement and motivation, feeling of being ahead of time.

### Suggested activities using ICT:

1. Working of a human heart
2. Cross and self-pollination in flowering plants
3. Working of electric motor and generator
4. Occurrences of cyclones, tornadoes, hurricanes
5. Functioning of a kidney

#### USEFUL LINKS

<https://youtu.be/46u2ON6d4mg>

<https://youtu.be/iE8MLbuEJs>

<https://youtu.be/gQyamjPrw-U>

[https://youtu.be/j\\_F4limaHYI](https://youtu.be/j_F4limaHYI)

<https://www.youtube.com/watch?v=82mW8bpcSyU>

## 4.8 Differentiation



- In Science, differentiation starts at the **beginning of each unit**.
- Before you begin teaching a unit, for example on space, plants, rocks, minerals and so on, give your students a **pre-test** to see what information they already know.
- For example, if one of your science **objectives** is to teach students the names and order of the planets, then you can ask this question in a pre-test.
- If half of your class already knows this information, then here's an objective you can use for differentiation.
- This way, students who already know this information can learn something else about planets, and those who do not, can work on mastering the objective.

**Formal Pre-Tests before each unit, class discussions and making observations** about students who are answering questions correctly are some methods of finding out at what level the students already are.

This strategy requires teachers to differentiate their teaching by allocating tasks based on students' abilities, to ensure that no one gets left behind. Assigning classroom activities according to students' unique learning needs, means individuals with higher academic capabilities are stretched and those who are struggling, get appropriate support. It may also mean using a variety of instructional strategies at varying levels of difficulty based on the ability of each student.

Teachers can practice differentiation in the classroom by:

- Designing lessons based on students' ability.
- Handing out **worksheets that vary in complexity**.
- Grouping students according to shared interest, topic, or the ability for assignments.
- Assessing students' learning using formative assessment.



- Managing the classroom to create a safe and supportive environment.
- Continually assessing and adjusting lesson content to meet students' needs.

### Example : Differentiation

**Classes:** VIII-IX

**Unit:** Earth Sciences

**Objective:** To address a variety of learner needs and preferences

**Activity:**

**Step 1:** Give a pre-test to students and find out what information has already been mastered and what they still need to work on

**Step 2:** Design activities, discussions, lectures, and so on to teach information to students. The best way is to have two or three groups of students divided by their ability level.

**Step 3:** While you are instructing one group, the other groups are working on activities to further their knowledge of the concepts. While you are helping **one group** learn the planet names in order, **another group** is researching climate, size, and distance from the moon of each planet.

**Step 4:** Then the groups switch, and you instruct the second group on another objective from the space unit. The first group practices writing the order of the planets and drawing a diagram of them.

When you are using differentiation in science:

- Find websites on the current science unit that students can explore on their own.
- Allow students to work in small groups to create a project throughout the entire unit. For example, one group might create a solar system model to scale. Another group might write a play about the solar system. This is an activity these groups can work on while they are not working directly with you.

#### Benefits of using differentiation in science:

- Gets students excited to learn because it challenges them to expand their knowledge and skills.
- Prevents wastage of time on teaching the whole group concepts they have already mastered.

#### Another Differentiation Strategy:

**Flexible Grouping** involves grouping students together for delivering instruction. This can be as a whole class, a small group, or with a partner.

#### Flexible grouping:

- Creates temporary groups that can last an hour, a week, or even a month.
- It's not permanent, but a temporary way for students to work together in a variety of ways and configurations depending upon activity and learning outcomes.
- Using an educational tool such as a **quiz** can save hours because it automatically groups students and helps to easily identify individual and whole-class learning gaps.





## 4.9 Demonstration

A **visual approach** to examine information, ideas and processes. It is a teaching method that allows students to see the teacher actively engaged as a learner and a model rather than merely telling them what they need to know.

The word demonstration means to give demos or to perform a particular activity or concept. In the demonstration method, the teaching-learning process is carried out systematically.

**For the demonstration method to be successful, three things are necessary.**

- (a) The object being displayed during demonstration should not be too small.
- (b) During the demonstration, the language used should be clear and lucid so that students may understand concepts easily.
- (c) Students should be able to question teachers without any inhibition to remove their doubts..

### **Demonstration Method: Steps**

#### **(1) Planning and preparation**

- Preparation of subject matter/content
- Lesson planning
- Selection of materials related to the demonstration.

#### **(2) Introducing of the lesson-keeping in mind**

- individual differences
- Environment
- Experiences

*The lesson can also be started with some simple and interesting experiments, a common event or some internal story. The experiment should be able to hold the attention of students.*

#### **(3) Presentation of subject matter**

- The principle of reflective thinking should be kept in mind.
- The teacher should teach the students in such a way that their previous knowledge can be linked to their new knowledge.

#### **(4) Demonstration**

- The performance on the demonstration table should be precise and ideal for the student to receive it with clarity.
- The demonstration should be neat and clean.

#### **(5) Teaching Aids**

- Models, blackboard, graphs, etc. can be used during a demonstration.

#### **(6) Evaluation**

- In this last step, the evaluation of the whole demonstration should be done to make it more effective by inviting responses to a few questions.



### Example : Demonstration

**Classes:** VI-X

**Unit:** Light

**Objective:** To show the dispersion of light using a prism.

**Activity:** Dispersion of light.

**Apparatus:** Prism, source of white light, white screen

**Procedure:** A beam of white light is passed through prism and the spectrum is captured on a white screen. Light is sent through one of the rectangular faces, which enters the prism and exits through one of the other rectangular faces. Since different colours of light travel at different speeds, the refractive index is different for each colour. As a result, when white light passes through the refracting surface of the prism, its components bend into different angles, causing the single beam of light to separate. Then, the different colours of light bend again because of the refraction caused by the second rectangular surface.

In this way, white light gets split into its component colours upon passing through a glass prism.

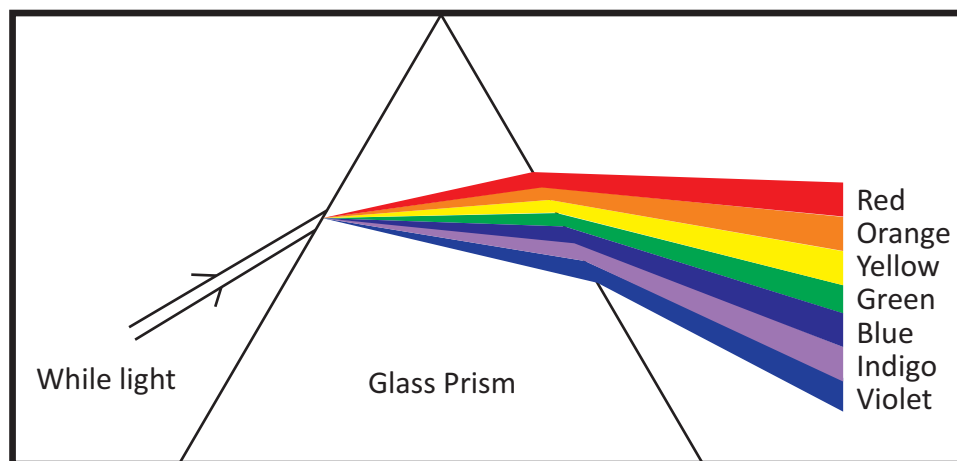


Figure 10: Dispersion of Light

#### 4.10 Project - Based Learning

It is a dynamic classroom approach in which students actively explore real-world problems and challenges and acquire deeper knowledge.

Students work on a project over an extended period from a week up to a semester. They are engaged in solving a **real-world problem** or answering a **complex question**. They demonstrate their knowledge and skills by developing a public product or presentation for a real audience.

As a result, doing an authentic and meaningful project, students develop intensive content knowledge as well as critical thinking, creativity, and communication skills.



### Features of Project-Based Learning:

- ❖ is organized around an open-ended driving question or challenge.
- ❖ creates a need to know essential content and skills.
- ❖ requires an inquiry to learn and/or create something new.
- ❖ requires critical thinking, problem-solving, collaboration, and various forms of communication.
- ❖ allows some degree of student voice and choice.
- ❖ incorporates feedback and revision.
- ❖ results in a publicly presented product or performance.

### A Project Report should fulfil the given criteria:

- ❖ Introduction
- ❖ Aims and Objectives of the study
- ❖ Hypothesis
- ❖ Need Statement
- ❖ Work Plan
- ❖ Methodology
- ❖ Observations
- ❖ Data Analysis and Interpretation
- ❖ Results
- ❖ Conclusion
- ❖ Solution to the Problem

### Example : Project - Based Learning

**Classes:** VIII-X

**Unit:** Health

- Objective:**
- To identify and document various available Multi-Purpose Tree Species in a certain locality
  - To identify, analyze and document different uses of the available Multi-Purpose Tree Species
  - To evaluate the economic benefits of the MPTS
  - To find out any management options/approaches needed for maintaining the MPT species along with any threats towards their availability

**Activity:** A Study on the Role of Multi-Purpose Tree Species (MPTS) in your Locality

### Introduction

Multi-purpose tree species refers to the species of plants which have more than one economic value. Such species are highly important in the context of achieving the goal of sustainable production and consumption. (For example, bamboo, banana, coconut, jackfruit etc.)

### Methodology

- Selection of the study site/locality.
- Literature survey and inventurisation (a detailed itemized list) of available knowledge for scientific documentation of the species available.
- Document various uses of different MPTS available in the locality, associated management and cultural practices, traditional beliefs, and norms associated with the MPTS.
- Calculate the economic value of the services provided and products derived by the MPTS.
- Observe, analyze and document various benefits of these MPTS.
- Document any potential threat to the availability of these MPTS.



Figure 11: Banana Tree - An Example of MPTS

### Expected Outcomes

- This study will help to identify various Multi-Purpose Tree Species available in a specific locality along with various aspects of its uses, potential benefits, socio-cultural impacts as well as management practices.
- Further, the study will also contribute towards identifying the potential threats to these species.
- It will help in the identification and validation of proper management approaches. This may also lead to some innovative approaches for the management of these species which can increase their potential for sustainability.

### 4.11 Inductive Approach

Inductive means '**to draw or to lead**'. Developed by Francis Bacon, it is the process in which generalizations of Science are derived through the known facts. Learners discover and experience phenomenon, raise questions and formulate generalizations from the learning experience that they are exposed to, to learn on their own.

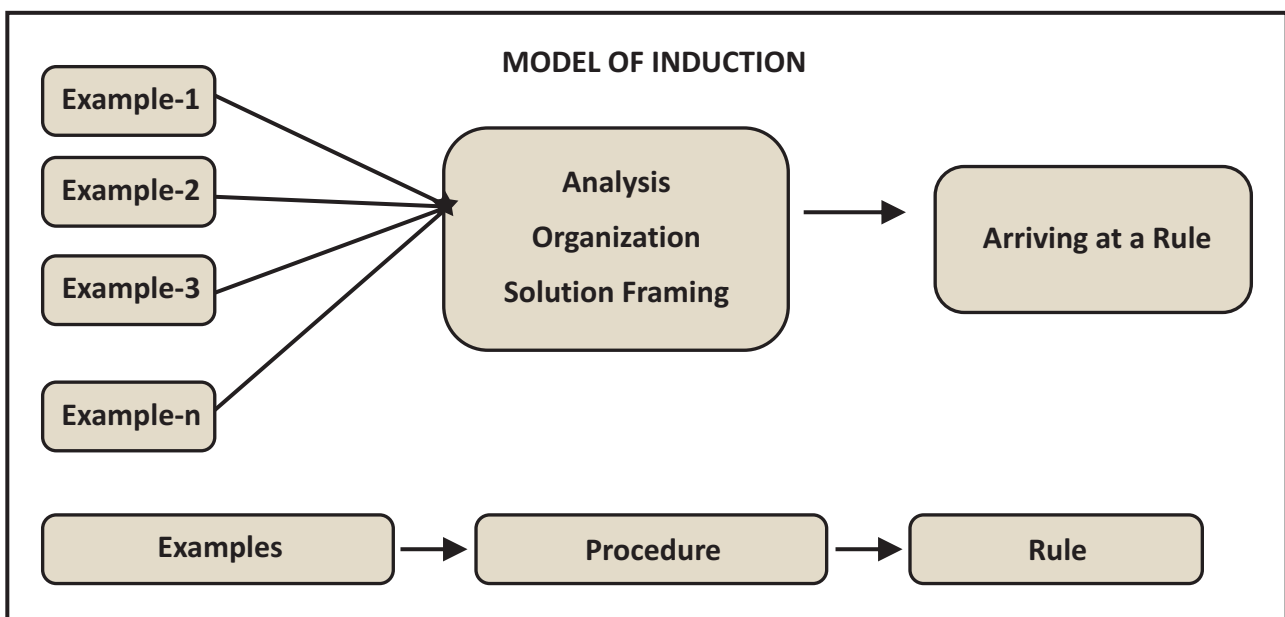
The strategies of *Discovery Teaching* and *Inquiry* are associated with *Inductive Teaching*. It is up to the teacher to create and present activities for the students to generate sound generalizations. While the students are in the exploration process, the teacher must guide them so that ambiguities may be avoided/resolved.



The Inductive approach is also called as a rule approach. This approach moves from known to unknown, simple to complex, specific to general, concrete to abstract and example to rule. Inductive teaching allows opportunities for students to interact with each other. Brainstorming, buzz sessions, and experiments are some examples of inductive teaching methods.

#### Inductive Approach—Steps

- ❖ Presentation of the area that is to be studied
- ❖ Gathering and evaluating the data gathered
- ❖ Creating ideas based on the learning experience
- ❖ Producing hypotheses
- ❖ Verifying the concepts gathered
- ❖ Utilization of the concepts learned
- ❖ Putting it all together



#### Inductive Approach-Advantages:

- ✓ Logical approach - develops thinking and observation.
- ✓ Psychological approach - provides more scope for students' participation.
- ✓ Discourages rote memory - students get more avenues to think.
- ✓ Independent thinking, higher-order thinking skills and authentic learning results.
- ✓ It develops self-confidence.
- ✓ Students collaborate - improve their personal and social skills.



### Example : Inductive Approach

**Class:** IX

**Unit:** Laws of Motion

**Objective:** To study the effect of force on an object

**Material:** Coins, cups, cards (large enough to cover the mouth of the cup)

**Steps:**

- Take a tumbler and cover it with a stiff piece of playing card.
- Place a 5 rupee coin at the centre of the card.
- Give the card a sharp horizontal flick with a finger.
- If the student does it fast, then the card shoots away, allowing the coin to fall vertically into the glass tumbler due to its inertia.
- The inertia of the coin tries to maintain its state of rest even when the card flies off.

**Conclusion:** This examples illustrate that there is a resistance offered by any stationary object to change its state of rest. If it is at rest, it tends to remain at rest. This property of an object is called inertia. Similarly, when the branch of a tree is shaken vigorously, all the leaves fall; only the carom coin at the bottom of the pile is removed when a fast moving striker hits it; when a carpet is beaten, all the dust particles fall due to the inertia.



*Our task, regarding creativity, is to help children climb their own mountains, as high as possible. No one can do more.*

*Loris Malaguzzi*

*Tell Me and I Forget,  
Teach Me and I Remember,  
Involve Me and I Learn.*

*Benjamin Franklin*



#### 4.12 What Do Great Science Teachers Do?

The advent of technology has brought about massive changes in the economy, in the way we communicate and relate to each other, and in the way we learn. However, our educational institutions were built chiefly for the industrial era, rather than a digital era. Thus, teachers are faced with the enormous challenge of change; the challenge to ensure that we are developing the kinds of students that are fit for an increasingly uncertain, complex and ambiguous future. We need to think about the changes that are to be effected in our teaching methods.



#### Great Science Teachers:

- are passionate about their subject and infuse enthusiasm in their students.
- are thorough with content and constantly update themselves.
- are keenly aware that they don't know everything.
- are willing to grow as professionals and try new and innovative pedagogical skills.
- plan engaging activities for their lessons to meet students' needs, interests and abilities.
- navigate tricky science concepts, use active learning approaches.
- anticipate and work with students' preconceptions and misconceptions.
- reflect daily upon their teaching practices.
- have a methodical, meticulous and logical approach.
- evaluate and assess students' progress periodically.
- can explain concepts in the curriculum in diverse ways to students with different learning styles.
- develop critically thinking students who understand scientific processes.
- focus on hands-on and minds-on strategies and process-oriented teaching.
- have excellent communication skills to teach a diverse group of students.

#### 4.13. Government's Initiatives to Enhance Scientific Literacy

##### Atal Tinkering Laboratories (ATL):

With the vision to create scientific temper and cultivate the spirit of curiosity and innovation among young minds, the Government of India has set up a network of Atal Tinkering Laboratories (ATL). The ATL labs teach students pan-India, the essential 21<sup>st</sup> century skills which will help them develop their professional and personal skills. Young children will get a chance to work with tools and equipment to understand what, how, and why aspects of STEM (Science, technology, engineering, and mathematics). ATL contain educational and learn 'Do it yourself' kits and equipment on electronics, robotics, open-source microcontroller boards, sensors and 3-D printers.



Figure 12: Atal Tinkering Labs in Schools

### National Children Science Congress (NCSC)

National Children Science Congress (NCSC) is a forum for the children of the age-group 10-17 years, both from formal school system as well as from out of school, to exhibit their creativity and innovativeness, and particularly, their ability to solve a societal problem experienced locally by using methods of science.



Figure 13: Exhibits of NCSC





### **Jawaharlal Nehru National Science, Mathematics and Environment Exhibition for Children**

NCERT organizes Jawaharlal Nehru National Science, Mathematics and Environment Exhibition for Children every year to encourage, popularize and inculcate scientific temper among the children of the country. The children get an opportunity to showcase their talents in the application of knowledge in the field of science and mathematics. The competition is held in two phases- at the state level and at the national level.



**Figure 14:** Students demonstrating their exhibits in Jawaharlal Nehru National Science Exhibition

### **Kishore Vaigyanik Protsahan Yojna**

The Kishore Vaigyanik Protsahan Yojana (KVPY) is an on-going National Program of Fellowship in Basic Sciences, initiated and funded by the Department of Science and Technology, Government of India, to attract exceptionally and highly motivated students for pursuing basic science courses and research career in science. The objective of the program is to identify students with talent and aptitude for research; help them realize their academic potential; encourage them to take up research careers in Science, and ensure the growth of the best scientific minds for research and development in the country. The selection of students is made from those studying in XI standard to 1<sup>st</sup> year of any Undergraduate Program in Basic Sciences.

### **Science Olympiads**


Science Olympiad is an annual competition in which students compete in events pertaining to various scientific disciplines including Earth Science, Biology, Chemistry, Physics, and Engineering. There are multiple levels of competition- regional, state and national. Winners receive several kinds of awards including medals, trophies and plaques, as well as scholarships.

*The best teachers are those who show you where to look, but don't tell you what to see.*

*Alexandra K Trenfor*



**CHAPTER 5**  
**PUBLISHED PISA TEST ITEMS**  
**ON SCIENTIFIC LITERACY**  
Excerpts from: **Take The Test E-booklet**

<p><b>Test Item :1</b></p> <p><b>Unit 10 –</b> <b>ACID RAIN</b> <b>Page – 209</b></p> <p><b>Question 10.1</b></p>	<p>Below is a photo of statues called Caryatids that were built on the Acropolis in Athens more than 2500 years ago. The statues are made of a type of rock called marble. Marble is composed of calcium carbonate.</p>  <p>In 1980, the original statues were transferred inside the museum of the Acropolis and were replaced by replicas. The original statues were being eaten away by acid rain.</p> <p><b>Normal rain is slightly acidic because it has absorbed some carbon dioxide from the air. Acid rain is more acidic than normal rain because it has absorbed gases like sulfur oxides and nitrogen oxides as well. Where do these sulfur oxides and nitrogen oxides in the air come from?</b></p> <p><b>The effect of acid rain on marble can be modeled by placing chips of marble in vinegar overnight. Vinegar and acid rain have about the same acidity level. When a marble chip is placed in vinegar, bubbles of gas form. The mass of the dry marble chip can be found before and after the experiment.</b></p>
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<p><b>Answer</b> <b>(Page 269)</b></p>	<p><b>Full credit:</b></p> <ul style="list-style-type: none"><li>• Responses that mention any one of these: car exhausts, factory emissions, <i>burning fossil</i> fuels such as oil and coal, gases from volcanoes or other similar things.</li><li>• Burning coal and gas.</li><li>• Oxides in the air come from pollution from factories and industries.</li><li>• Volcanoes.</li><li>• Fumes from power plants.</li><li>• They come from the burning of materials that contain sulfur and nitrogen.</li><li>• Responses that include an incorrect as well as a correct source of the pollution.</li></ul>
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<p><b>Answer (Page 269)</b></p>	<ul style="list-style-type: none"> <li>• Fossil fuel and nuclear power plants. (<i>Nuclear power plants are not a source of acid rain.</i>)</li> <li>• The oxides come from the ozone, atmosphere, and meteors coming toward Earth, also the burning of fossil fuels.</li> <li>• Responses that refer to “pollution” but do not give a source of pollution that is a significant cause of acid rain.</li> <li>• Pollution.</li> <li>• The environment in general, the atmosphere we live in – e.g., pollution.</li> <li>• Gasification, pollution, fires, cigarettes.</li> <li>• Pollution such as from nuclear power plants.</li> </ul> <p><b>No credit:</b></p> <ul style="list-style-type: none"> <li>• Other responses, including responses that do not mention “pollution” and do not give a significant cause of acid rain.</li> <li>• They are emitted from plastics.</li> <li>• They are natural components of air.</li> <li>• Cigarettes.</li> <li>• Coal and oil. (<i>Not specific enough – no reference to “burning”</i>)</li> <li>• Nuclear power plants.</li> <li>• Industrial waste. (<i>Not specific enough</i>)</li> <li>• Missing</li> </ul> <p>❖ Answering this question correctly corresponds to a difficulty level of 506 score points on the PISA 2006 science scale. Across OECD countries, 58% of students answered correctly. The question assesses students' competencies in explaining phenomena scientifically.</p>
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<p><b>Question 10.2</b></p>	<p><b>A marble chip has a mass of 2.0 gram before being immersed in vinegar overnight. The chip is removed and dried the next day. What will the mass of the dried marble chip be?</b></p>
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<p><b>Answer (Page 270)</b></p>	<p><b>Full credit:</b> A. Less than 2.0 grams</p> <p><b>No credit:</b> Other responses and missing</p> <p>Answering this question correctly corresponds to a difficulty level of 460 score points on the PISA 2006 science scale. Across OECD countries, 67% of students answered correctly. The question assesses students' competencies in using scientific evidence.</p>
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<p><b>Question 10.3</b></p>	<p><b>Students who did this experiment also placed marble chips in pure (distilled) water overnight. Explain why the students included this step in their experiment.</b></p>
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<p><b>Answer</b> <b>(Page 270)</b></p>	<p><b>Full credit:</b> Responses such as</p> <ul style="list-style-type: none"> <li>• To show that the acid (vinegar) is necessary for the reaction.</li> <li>• To make sure that rainwater must be acidic like acid rain to cause this reaction.</li> <li>• To see whether there are other reasons for the holes in the marble chips</li> <li>• Because it shows that the marble chips don't just react with any fluid since water is neutral.</li> </ul> <p><b>Partial credit:</b> Responses that compare with the test of vinegar and marble, but do not make clear that this is being done to show that the acid (vinegar) is necessary for the reaction.</p> <ul style="list-style-type: none"> <li>• To compare with the other test tube.</li> <li>• To see whether the marble chip changes in pure water.</li> <li>• The students included this step to show what happens when it rains normally on the marble.</li> <li>• Because distilled water is not acid.</li> <li>• To act as a control.</li> <li>• To see the difference between normal water and acidic water (vinegar).</li> </ul> <p><b>No credit:</b> Other responses and missing.</p> <p>Answering this question correctly corresponds to a difficulty level of 717 score points on the PISA 2006 science scale. Giving a partially correct answer corresponds to a difficulty level of 513 score points on the PISA 2000 science scale. Across OECD countries, 36% of students answered correctly. The question assesses students' competencies in identifying scientific issues.</p>
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<p><b>Question 10.4</b> <b>(Attitude)</b> <b>Page –210</b></p>	<p><b>How much do you agree with the following statements?</b> <b>Tick only one box in each row:</b></p>				
		<b>Strongly Agree</b>	<b>Agree</b>	<b>Disagree</b>	<b>Strongly Disagree</b>
	Knowing which human activities contribute most to acid rain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Learning about technologies that minimize the emission of gases that cause acid rain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Understanding the methods used to repair buildings damaged by acid rain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	





<b>Question 10.5</b> (Attitude) Page –210	<b>How much do you agree with the following statements?</b> <b>Tick only one box in each row</b>				
		<b>Strongly Agree</b>	<b>Agree</b>	<b>Disagree</b>	<b>Strongly Disagree</b>
	The prevention of ancient ruins should be based on scientific evidence concerning the causes of damage.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Statements about the causes of acid rain should be based on scientific research.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

<b>Test Item : 2</b> <b>UNIT 14 : BUSES</b> Page 216 <b>Question 14.1</b>	A bus is driving along a straight stretch of road. The bus driver, named Ray, has a cup of water resting on the dashboard.	
	Suddenly Ray has to slam on the brakes. <b>a The water will stay horizontal.</b> <b>b The water will spill over side 1.</b> <b>c The water will spill over side 2.</b> <b>d The water will spill but you cannot tell if it will spill at side 1 or side 2.</b>	

<b>Answer</b> Page 273	<b>Full Credit:</b> C. The water will spill over side 2. <b>No Credit:</b> Other responses and missing <i>The process assessed is demonstrating knowledge and understanding</i>
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<b>Question 14.2</b>	Ray's bus is, like most buses, powered by a petrol engine. These buses contribute to environmental pollution. Some cities have trolleybuses: they are powered by an electric engine. The voltage needed for such an electric engine is provided by overhead lines (like electric trains). <b>The electricity is supplied by a power station using fossil fuels. Supporters for the use of trolleybuses in a city say that these buses don't contribute to environmental pollution. Are these supporters right?</b>
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<b>Answer</b> <b>Page 273</b>	<p><b>Full credit:</b> Gives an answer in which it is stated that the power station also contributes to environmental pollution, such as:</p> <ul style="list-style-type: none"><li>• No, because the power station causes environmental pollution as well</li><li>• Yes, but this is only true for the city itself; the power station however causes environmental pollution.</li></ul> <p><b>No credit:</b> No or yes without a correct explanation and missing.</p> <ul style="list-style-type: none"><li>• The process assessed is demonstrating knowledge and understanding</li></ul>
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<b>Test Item : 3</b> <b>UNIT 16 : FLIES</b>  <b>Page 218</b>	<p>A farmer was working with dairy cattle at an agricultural experiment station. The population of flies in the barn where the cattle lived was so large that the animals' health was affected. So the farmer sprayed the barn and the cattle with a solution of insecticide A. The insecticide killed nearly all the flies. Sometime later, however, the number of flies was again large. The farmer again sprayed the insecticide. The result was similar to that of the first spraying. Most, but not all of the flies were killed. Again, within a short time the population of flies increased, and they were again sprayed with the insecticide. This sequence of events was repeated five times: then it became apparent that insecticide A was becoming less and less effective in killing the flies. The farmer noted that one large batch of the insecticide solution had been made and used in all the sprayings. Therefore he suggested the possibility that the insecticide solution decomposed with age.</p>
<b>Question 16.1</b>	<p><b>The farmer's suggestion is that the insecticide decomposed with age. Briefly explain how this suggestion could be tested?</b></p>

<b>Answer</b> <b>Page 274</b>	<p><b>Full credit:</b> Responses in which three variables (type of flies, age of insecticide, and exposure) are controlled, such as :</p> <ul style="list-style-type: none"><li>• Compare the results from a new batch of the insecticide with results from the old batch on two groups of flies of the same species that have not been previously exposed to the insecticides.</li><li>• Some flies could be taken. If they would both be put in a separate box you could use a new spray and an older spray and see what the results are. (<i>Note: Although the same species is not mentioned, it is implied that the flies are the same type, and that the flies have not been previously exposed.</i>)</li><li>• Make one big batch of spray. Have 2 groups of flies and spray each group every six months. Spray group one with the big batch, and group 2 a new batch each time. (<i>Note: Although the same species is not mentioned, it is implied that the flies are the same type, and that the flies have not been previously exposed.</i>)</li></ul> <p><b>Partial credit:</b> Responses in which three variables (type of flies, age of insecticide, and exposure) are controlled, such as :</p> <ul style="list-style-type: none"><li>• Compare the results from a new batch of the insecticide with results from the old batch on the flies in the barn.</li></ul>
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	<ul style="list-style-type: none"><li>• Try a new bottle of it, then wait till it gets a bit older and the flies come back and then try again.</li></ul> <p><i>Note: Reproduction of what the farmer experienced, controlling the age of the insecticide and type of flies (“the flies” is interpreted to mean the same flies).</i></p> <p><b>No credit:</b> Other responses and missing He could test it every year to see if it is not old and would still work. (Note: Does not indicate how the insecticide would be tested.)</p> <ul style="list-style-type: none"><li>• <i>The competency being assessed is identifying evidence.</i></li></ul>
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<b>Question 16.2</b>	<b>The farmer's suggestion is that the insecticide decomposed with age. Give two alternative explanations as to why “insecticide A was becoming less and less effective...”</b>
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<b>Answer Page 275</b>	<p><b>Full credit:</b> Responses that give any one explanation a) that flies with resistance to the insecticide survive and pass on that resistance to later generations (also credit for “immunity:” although it is recognized that it is not strictly analogous to “resistance”), as well as one of these b): a change in the environmental conditions (such as temperature), or a change in the way the insecticide was applied.</p> <ul style="list-style-type: none"><li>• <b>Explanation 1:</b> With the repeated use of the same insecticide the flies were becoming immune to the formula.</li><li>• <b>Explanation 2:</b> Over time, chemicals in the insecticide rose to the top of the spray-can leaving water diluted (ineffective) at the bottom.</li><li>• <b>Explanation 1:</b> The flies were becoming immune to the spray.</li><li>• <b>Explanation 2:</b> Heat may make it decompose and temperature change.</li><li>• <b>Explanation 1:</b> Maybe the flies developed a defense gene so that insecticide would not work.</li><li>• <b>Explanation 2:</b> He (the farmer) used less each time. (<i>Note: Defense gene is allowed as an alternative to resistance.</i>)</li></ul> <p><b>Partial credit:</b> Give one explanation of type a) or type b).</p> <ul style="list-style-type: none"><li>• He might not have sprayed it properly.</li><li>• The flies could have built up immunity.</li><li>• There were different types of flies each time. (<i>Note: A clear distinction is made between different types of flies in this example; it is not referring to new flies coming into the area.</i>)</li><li>• <b>Explanation 1:</b> The temperature got very hot and affected the insecticide. <b>Explanation 2:</b> The farmer did not spray the insecticide on the flies properly</li></ul> <p><b>No credit:</b> Other responses, including new flies moving to the barn from nearby (unsprayed) areas, and missing.</p>
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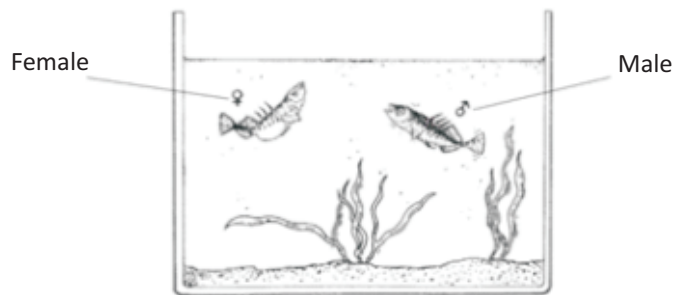
- The flies could have been breeding.
- Because every time he sprayed it became less and less effective.
- When there is more of it in the can, it is stronger. (Note: A clear relationship between volume and concentration is not given.)
- The process being assessed is recognizing questions.

**Test Item :4**

**UNIT 23:  
STICKLEBACK  
BEHAVIOUR**

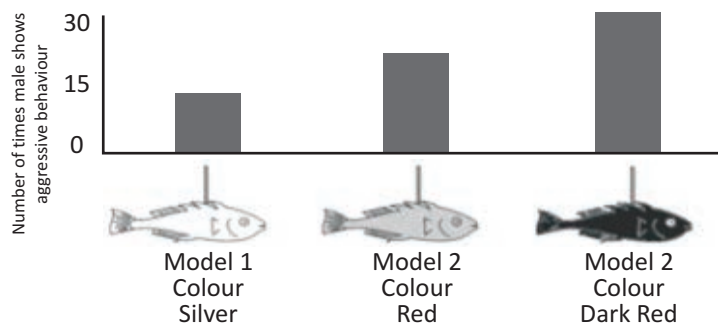
Page –230

The stickleback is a fish that is easy to keep in an aquarium.



During the breeding season, the male stickleback's belly turns from silver-coloured to red. The male stickleback will attack any competing male that comes into his territory, and try to chase it away. If a silver-coloured female approaches, he will try to guide her to his nest so she will lay her eggs there.

In an experiment, a student wants to investigate what will make the male stickleback show aggressive behavior. A male stickleback is alone in the student's aquarium. The student has made three wax models attached to pieces of wire. He hangs them separately in the aquarium for the same amount of time. Then the student counts the number of times the male stickleback reacts aggressively by pushing against the wax figure. The results of the experiment are shown below:



Question 23.1

**What is the question that this experiment is attempting?**





Answer  
Page 280

**Full credit:** Questions such as:

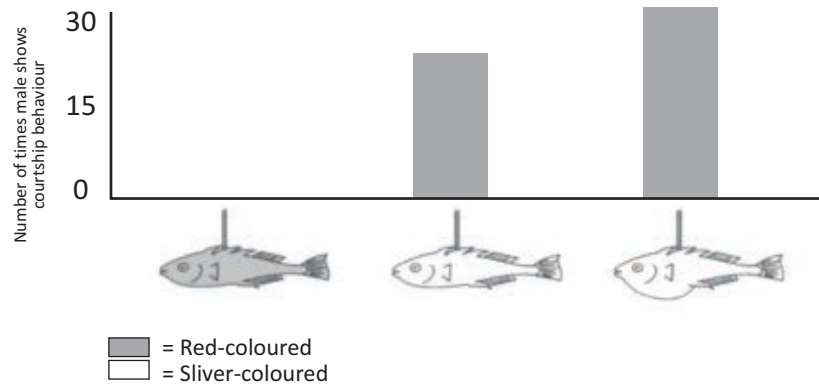
- What colour elicits the strongest aggressive behavior by the male stickleback?
- Does the male stickleback react more aggressively to a red-coloured model than to a silver-coloured one?
- Is there a relationship between colour and aggressive behavior?
- Does the colour of the fish cause the male to be aggressive?
- What fish colour does the stickleback find most threatening?

**No credit:**

- Other responses (including all responses that do not refer to the *colour* of the stimulus/model/fish
- What colour will elicit aggressive behavior in the male stickleback. (*No comparative aspect.*)
- Does the colour of the female stickleback determine the aggressiveness of the male? (*The first experiment is not concerned with the gender of the fish.*)
- Which Model does the male stickleback react to most aggressively: (*specific reference must be made to the colour of the fish/model.*)
- Missing
- The competency being assessed is identifying the scientific issue

### Question 23.2

During breeding time, if the male stickleback sees a female he will try to attract the female with courtship behavior that looks like a little dance. In a second experiment, the courtship behavior is investigated. Again, three wax model on a piece of wire are used. One is red-coloured, two are silver-coloured with one having a flat belly and the other a round belly. The student counts the number of times (in a given amount of time) that the male stickleback reacts to each model by showing courtship behavior. The result of this experiment are shown below:



Three students each draw a conclusion based on the results of this second experiment. Are their conclusions correct according to the information given in the graph? Circle “Yes” or “No” for each conclusion.



	Is this conclusion correct according to the information in the graph	Yes/No
	The red colour causes courtship behavior by the male stickleback.	Yes/No
	The flat-bellied female stickleback causes most courtship behavior from a stickleback male.	Yes/No
	The male stickleback shows courtship behavior more often to a round-bellied female than to a flat-bellied female.	Yes/No

<b>Answer Page 281</b>	<p>Full credit: No, No, Yes in that order.</p> <p>No credit: Other responses and missing</p> <ul style="list-style-type: none"> <li>The competency being assessed is using scientific evidence.</li> </ul>
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**Question 23.3**

Experiments have shown that male sticklebacks react with aggressive behavior to models with a red belly, and with courtship behavior to models with a silver belly. In a third experiment, the following four models were used *in turn*.

= Red-coloured  
 = Silver-coloured

The three diagrams below show the possible reactions of a male stickleback to each of the above models. Which one of these reactions would you predict for each of the four models?

= Number of aggressive behaviours  
 = Number of courtship behaviours

Fill in either A, B or C as the result for each model

	Reaction
Model 1	
Model 2	
Model 3	
Model 4	

<b>Answer Page 281</b>	<p>Full credit: C, A, C, B in that order.</p> <p>Partial credit: Other responses and missing</p> <ul style="list-style-type: none"> <li>The competency being assessed is using scientific evidence.</li> </ul>
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<p><b>Test Item :5</b>  <b>UNIT 30 :</b>  <b>TRANSIT OF</b>  <b>VENUS</b>  <b>Page – 245</b></p>	<p>On 8<sup>th</sup> June 2004, the planet Venus could be seen passing in front of the Sun when viewed from many places on Earth. This is called a “transit” of Venus and happens when its orbit takes Venus between the Sun and Earth. The previous transit of Venus occurred in 1882 and another is predicted to occur in 2012. Below is a picture of the transit of Venus in 2004. <b>A telescope was pointed at the Sun and the image projected onto a white card.</b></p> <div data-bbox="638 488 1109 784" data-label="Image"> </div> <p><b>Question 30.1</b> Why was the transit observed by projecting the image onto a white card, rather than by looking directly through the telescope?</p> <ol style="list-style-type: none"> <li>The sun's light was too bright for Venus to show up.</li> <li>The sun is big enough to see without magnification.</li> <li>Viewing the sun through a telescope may damage your eyes.</li> <li>The image needed to be made smaller by projecting it onto a card.</li> </ol>
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<p><b>Answer</b>  <b>Page 286</b></p>	<p><b>Full credit:</b> C: Viewing the Sun through a telescope may damage your eyes.  <b>No credit:</b> Other responses and missing</p> <ul style="list-style-type: none"> <li>The competency being assessed is explaining phenomena scientifically.</li> </ul>
<p><b>Question 30.2</b></p>	<p>When viewed from Earth, which one of the following planets can be seen in transit across the face of the Sun at certain times?</p> <ol style="list-style-type: none"> <li>Mercury</li> <li>Mars</li> <li>Jupiter</li> <li>Saturn</li> </ol>
<p><b>Answer</b>  <b>Page 286</b></p>	<p><b>Full credit:</b> a) Mercury.  <b>No Credit:</b> Other responses and missing</p> <ul style="list-style-type: none"> <li>The competency being assessed is explaining phenomena scientifically.</li> </ul>
<p><b>Question 30.3</b></p>	<p>Several words have been underlined in the following statement.  <u>Astronomers</u> <u>predict</u> that, as seen from <u>Neptune</u> there will be a <u>transit</u> of <u>Saturn</u> across the <u>Sun's</u> face later this <u>century</u>. Which <i>three</i> of the underlined words would be most useful in an internet or library search to find out when this transit might occur?</p>
<p><b>Answer</b>  <b>Page 286</b></p>	<p><b>Full credit:</b> Responses referring to transit/Saturn/Neptune only.  <b>No credit:</b> Other responses and missing</p> <ul style="list-style-type: none"> <li>Identify keywords to search for scientific information on a given topic is a component of the competency identifying scientific issues.</li> </ul>



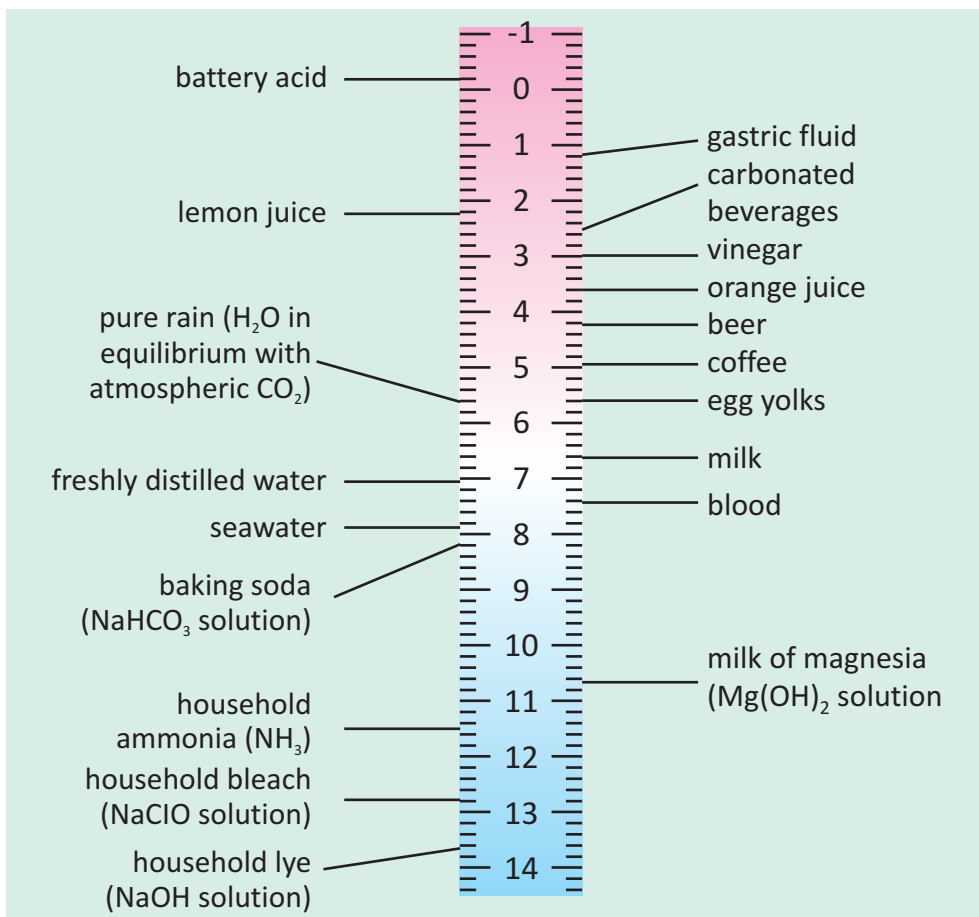
## CHAPTER 6

# SAMPLE TEST ITEMS ON SCIENTIFIC LITERACY

### Test item: 1

#### The pH scale

The pH scale is a negative logarithmic scale. The logarithmic part means that pH changes by 1 unit for every factor of 10 changes in concentration of  $H^+$ . There is an inverse relationship between pH and  $[H^+]$ ; when pH increases,  $[H^+]$  decreases and vice versa.



For a neutral solution pH = 7

For acidic solutions pH < 7

For basic solutions pH > 7

#### Question 1

**Concept Check:** Based on the pH scale given above, which solution is more acidic – orange juice or vinegar?

Competency	Evaluate Scientific Enquiry
Knowledge System	Physical Systems
Context	Global
Cognitive Demand	Medium
Question Format	Close Constructed



### Question 2

A buffer solution is an aqueous solution consisting of a mixture of a weak acid and its conjugate base, or vice versa. Its pH changes very little when a small amount of strong acid or base is added to it. Buffer solutions are used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications. Buffers normally resist change in pH on dilution.

**Assertion A:** pH of a buffer solution does not change on dilution.

**Reason R:** On dilution, the ratio of concentration of salt and acid (or base) remains unchanged.

Choose the correct option and justify your answer.

- a) A and R are true, R is the correct explanation of A
- b) A and R are true, R is not the correct explanation of A
- c) A is true but R is false
- d) A is false but R is true

---

Competency	Evaluate Scientific Enquiry
Knowledge System	Physical Systems
Context	Global
Cognitive Demand	Medium
Question Format	Open Constructed

### Question 3

**Statement 1:** The blood carries  $\text{CO}_2$  to the lungs, where it is exhaled. As  $\text{CO}_2$  accumulates in the blood, the pH of the blood decreases (acidity increases). The brain regulates the amount of  $\text{CO}_2$  that is exhaled by controlling the speed and depth of breathing (ventilation).

**Metabolic Acidosis:** A condition wherein a deficiency of bio-carbonate causes the blood to be overly acidic.

**Metabolic Alkalosis:** A condition wherein an excess of bicarbonate causes the blood to be overly alkaline.

**Case Study:** Sheela, a 38-year-old woman, is admitted to a hospital in Delhi. Her laboratory results are as follows:

pH – 7.48

$\text{PCO}_2$  – Normal range

$\text{HCO}_3^-$  – Higher than normal

- a) What could be the ailment the woman is suffering from?
- b) Identify a possible cause of the woman's illness.

(a) \_\_\_\_\_

(b) \_\_\_\_\_

Competency	Explain Scientific Phenomena
Knowledge-System	Living Systems
Context	Global
Cognitive Demand	Medium
Question Format	Open Constructed



### SCORING .1

#### Full Credit

Vinegar has a pH of = 3.0 and orange juice has a pH of =3.6. Because the pH of vinegar is less than that of orange juice ( $3.0 < 3.6$ ), vinegar has a higher concentration of  $H^+$ .

Therefore, vinegar is more acidic than orange juice.

### SCORING .2:

Full Credit – Option A

No Credit – for other responses

**Explanation:** On dilution pH of buffer solution remains unchanged because the ratio of concentration of salt and acid (or base) remains unchanged.

### SCORING .3:

Full Credit

- Metabolic alkalosis-increased pH and increased  $HCO_3^-$ .
- Illness has been caused by excessive loss of HCl from the stomach and loss of  $H^+$  ions from the body resulting in an excess of bicarbonate ions in the blood.

### Test item: 2

#### Wastewater

*Given below is a newspaper article published in Hindustan Times: 15th April 2019*

At least four sewage cleaners/workers choked to death while cleaning septic tanks in Tamil Nadu's Tiruppur district on Sunday, the police said. When one of the victims fell unconscious inside the tank after inhaling toxic gases, others who tried to save him also died. The fire department personnel rushed to the spot to rescue them, but their attempts failed as the men died immediately after inhaling the poisonous gases. The deceased were cleaning three tanks which were filled with sewage. The fatal incident happened while the second tank was being cleaned.

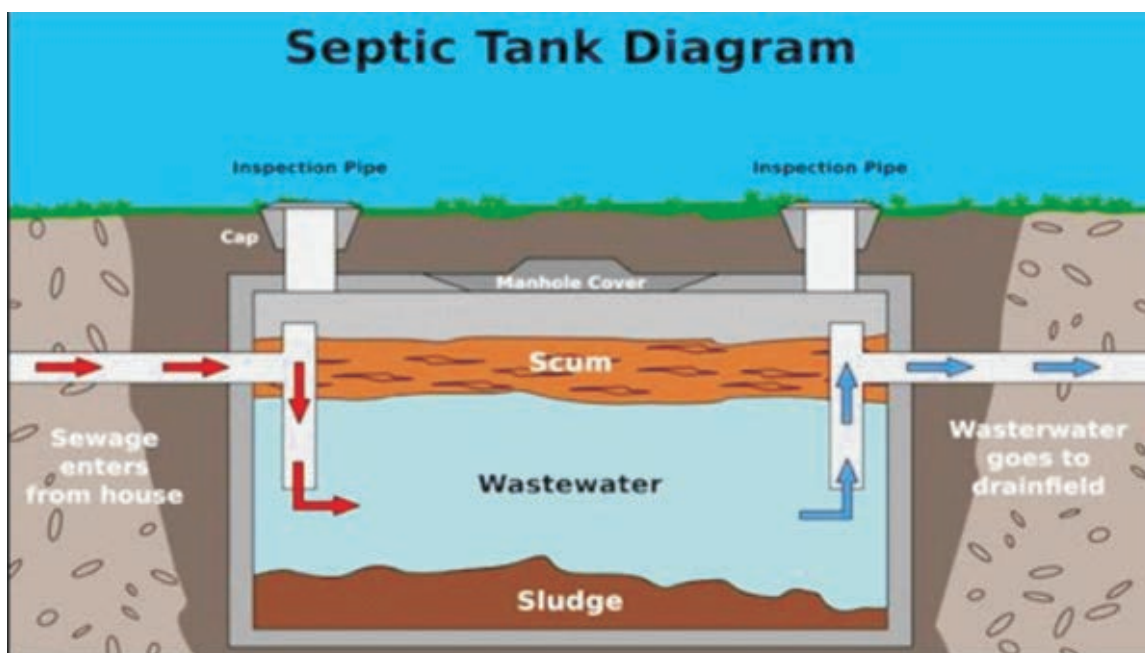


Figure 15: Shows the functioning of a Septic Tank



### Question 1

The given figure presents a diagrammatic view of the flow of wastewater through a septic tank of a given city. Given below in jumbled order is the sequence of events that take place inside the tank. Choose the option that best describes the sequence of the flow:

- a) Slowly, the solid wastes settle as sludge at the bottom of the tank.
- b) With time, the oil and grease float to the top as scum.
- c) Sewage enters through the inlet.
- d) Now, this treated/clarified wastewater goes to a drain field. Nature cleans it up further.
- e) Next, the aerobic bacteria present in the wastewater consume human waste, food waste, soaps and other unwanted matter remaining in the wastewater in the tank.

Tick the correct sequence:

- (i) c, a, d, b, e
- (ii) c, a, e, b, d
- (iii) c, a, b, e, d
- (iv) c, b, a, d, e

Competency	Recognizing Scientific Enquiry
Knowledge-System	Living Systems
Context	Global
Cognitive Demand	Medium
Question Format	Complex Multiple Choice

### Question 2

From the options given below, choose a pair of poisonous gases that workers could have inhaled when they were inside the septic tank:

- (a) Hydrogen sulphide ( $H_2S$ ), Methane ( $CH_4$ )
- (b) Oxygen ( $O_2$ ), Methane ( $CH_4$ )
- (c) Carbon monoxide ( $CO$ ), Sulphur dioxide ( $SO_2$ )

---

Competency	Identifying Evidence
Knowledge-System	Physical Systems
Context	Local
Cognitive Demand	Medium
Question Format	Multiple Choice



**Question 3**

A Septic tank can last for several years as long as it is properly maintained and regularly pumped. Excess sludge and scum need to be removed periodically as it prevents the aerobic breakdown of wastes and leads to the formation of “sewer gases” in the tanks.

How do you think poisonous gases are formed inside the septic tanks?

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Competency	Identifying Evidence
Knowledge-System	Physical Systems
Context	Local
Cognitive Demand	Medium
Question Format	Open Constructed Response

**Question 4**

The incident inside the septic tank was unfortunate and cost the lives of four men. The efforts of the fire department to save the sewage cleaners also went in vain.

What could have been the possible reasons for the fatal incident to have occurred while the cleaning of the 'second tank' was in progress?

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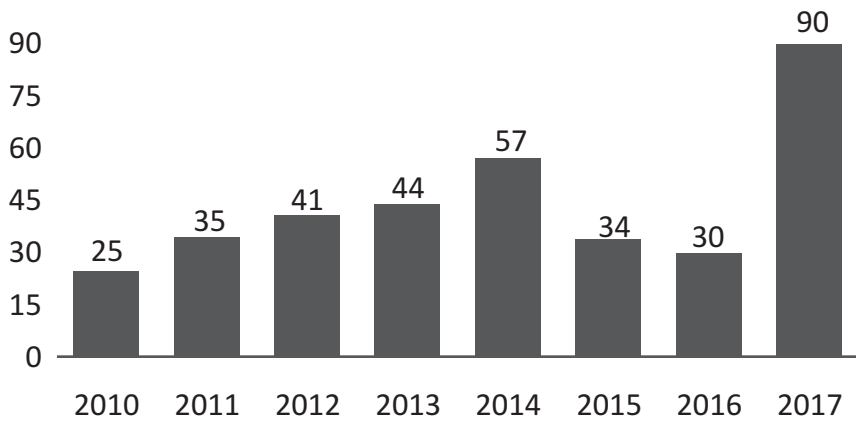


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Competency	Evaluates And Designs Scientific Enquiry
Knowledge-System	Physical Systems
Context	Local
Cognitive Demand	Medium
Question Format	Open Constructed Response

**Question 5**

Deaths in sewer lines/septic tanks



Scroll.in

Data: Safai Karamchari Andolan







The graph above shows an increase in the number of death of sewage cleaners in India over the past few years. Except in the year 2015-16, the number of deaths has been rising steadily. The govt. of India has passed strict laws and set guidelines that protect municipal employees and made it mandatory for the contractors to provide pumps and safety equipment for the workers.

What according to you could be the reason for this rise in the number of deaths?

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Competency	Interpret Data And Evidence Scientifically
Knowledge-System	Physical Systems
Context	Local
Cognitive Demand	Medium
Question Format	Open Constructed Response

### SCORING 1

Full credit: Option (iii)

No credit: Other response and missing

### SCORING 2

Full credit: (a)

No credit: Any other answer and missing

### SCORING 3

Full credit: Anaerobic respiration/decomposition of wastes in the sewage

No credit: Any other answer and missing

### SCORING 4

**Full Credit- Any of the following answers:**

- Workers had already inhaled toxic gases in septic tank-1, while entering tank
- Concentration of gases may have increased leading to the death.
- More concentration of toxic gases around/inside tank2

**Partial credit:** Any of the related above answers which is not complete or any other incomplete relevant answers.

**No credit:** Any other irrelevant answer and missing

### SCORING 5

**Full credit:** Any of the following reasons:

- Timely medical facilities not available
- Manual cleaning of sewage tanks continues
- Cleaning without proper safety measures
- More reporting of deaths

Any other relevant answer.

**Partial Credit:** Any of the related above answers which is not complete or any other incomplete relevant answers.

**No credit:** Any other irrelevant answer and missing



**Test item: 3**

**The occurrence of Elements and Extraction**

**Crustal abundance of Elements**

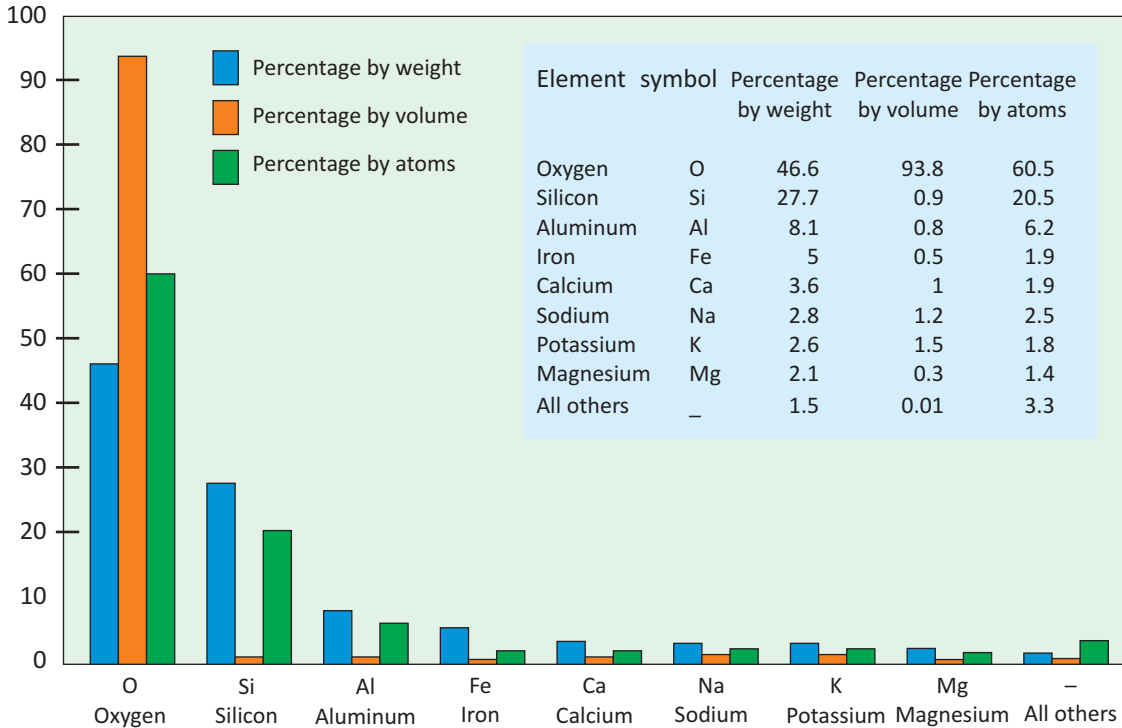
The Earth's crust has an average density of  $2800\text{kg/m}^3$  and a thickness of about 30 km. By mapping the major rock types and averaging their composition, the abundance of elements can be estimated. The crust is enriched in incompatible elements (e.g. K and Rb) as well as lithophile elements, but a few elements predominate, especially in silicate minerals, while some ore metals are rare (e.g. Cu and Sn).

Because the crust was formed from material extruded from the Earth's mantle, it is to be expected that the mantle is depleted in 'crustal' components. Oxygen (O) constitutes almost 50% of the Earth's crust by weight and is the most abundant element.

Other major elements include: silicon (Si), which is the second most abundant, constituting 27.72% of the crust by weight; aluminium (Al) third; sodium (Na); magnesium (Mg); calcium (Ca); and iron (Fe).

Other elements, including such desired metals as gold (Au), silver (Ag), and platinum (Pt) are rare in the crust and are used in Jewellery. The occurrence of elements is based on their reactivity. Various metals are found in the form of their halides, oxides, sulphides and carbonate ores from which they are extracted by metallurgical processes.

The following graph shows the relative abundance of different elements on the y-axis (in percentage by weight/volume/atoms) in earth crust against their atomic number on the X-axis.





### Question 1

Using the information given in the graph, identify which of the following is the most abundant in the earth's crust in terms of mass percentage.

- a) The element of the third period of the modern periodic table
- b) The metal among the transition metals
- c) The alkaline earth metal

---

Competency	Data Interpretation And Analysis
Knowledge-System	Physical Systems
Context	Global
Cognitive Demand	Medium
Question Format	Complex Multiple Choice

### Question 2

There is an interesting story about the Greek King Hero, who suspected his goldsmith of substituting cheaper alloys in a newly made crown, which should have been made entirely of pure gold. He assigned the task of proving his suspicion to Archimedes.

How do you think Archimedes applied the law of buoyancy to find the density of the metal used in the crown?

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Competency	Explain Phenomena Scientifically
Knowledge-System	Physical Systems
Context	Social
Cognitive Demand	Medium
Question Format	Open Constructed Response

### Question 3

Assuming that the density of pure gold is  $19.3 \text{ gm/cm}^3$ , if a piece of pure gold of  $2 \text{ cm}^3$  is dropped in water, how much mass of water will it displace?

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Competency	Explain Phenomena Scientifically
Knowledge-System	Physical Systems
Context	Social
Cognitive Demand	Medium
Question Format	Close Constructed Response



#### Question 4

Two persons claiming to possess expertise in polishing gold/silver jewellery visited a family. The lady of the house handed over her jewellery for polishing and was unable to perceive any change in the shining metals after the two men left. She, however, suspected that her trinkets weighed lighter and lodged a complaint with the police about the same.

a) During its investigation, the police seized the solution used by the accused and sent it for forensic. The lab technician detected traces of gold in it.

Why do you think the solution reacted with gold?

b) What could have been the chemical composition of the solution which dissolves the gold in it?

Competency	Explain Phenomena Scientifically
Knowledge-System	Physical Systems
Context	Social
Cognitive Demand	High
Question Format	Close Constructed Response

#### SCORING 1

**Full credit:** a) Silicon b) iron c) calcium

**No credit:** any other and missing

#### SCORING 2

**Full credit:** a) Archimedes found that the mass of displaced water was found to be more by pure gold instead of impure gold or Any other correct explanation.

b) When the gold is alloyed with silver, its density decreases.

**Partial Credit:** for incomplete answer

**No credit:** any other and missing

#### SCORING 3

**Full credit:** a) It will displace 2 gram of water assuming the density of water 1gm/cm<sup>3</sup>.

**No credit:** any other and missing

#### SCORING 4

**Full credit:** a) The goldsmith uses such chemicals to polish the gold articles which dissolve gold in it and stole the gold from jewellery.

b) Aquaregia (conc. HNO<sub>3</sub> and conc. HCl in 1:3) was used to dissolve the gold in it.

**Partial Credit:** for incomplete answer

**No credit:** Any other response and missing

# CHAPTER 7

## HOW TO MAP THE PISA STYLE TEST ITEMS WITH THE NCERT CURRICULUM



PISA assesses Scientific Knowledge in contexts that are relevant to the science curricula of participating countries

### 7.1 Identify the Level of the Test Item

- Relatively high proficiency L5 & L6
- Moderate proficiency L3 & L4
- Relatively low proficiency L1 & L2  
(cf. Section 8.6)

### 7.2 Identify the Skill Required

On the basis of the following specifications, identify which of the following skills is the test item/question testing.

- 1. Remembering:** Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.
- 2 Understanding:** Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas
- 3 Applying:** Solving problems in new situations by applying acquired knowledge, facts, techniques, and rules in a different way
- 4 Analyzing and Evaluating:**
  - ✓ Examine and break information into parts by identifying motives or causes.
  - ✓ Make inferences and find evidence to support generalizations.
  - ✓ Present and defend opinions by making judgments about information, the validity of ideas, or quality of work based on a set of criteria.
- 5 Creating:** Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions

### 7.3 Identify the Typology of the Test Item

- **MCQ**
  - Simple
  - Complex
- **Binary Choice:** These types of questions give students two options to select from. An example would be true/false, fact/opinion, yes/no, right/wrong and agree/disagree.
- **Open Constructed Response:** Students write a short explanation in response to a question, showing the methods and thought processes they had used in constructing their response.
- **Closed Constructed Response:** Students provide their responses with a limited range of acceptable answers. They ask students to fill in a word or a phrase in a specific text and usually require only simple recall or, at best an inference.
- **Cloze Gap:** A way of testing comprehension by removing words (usually every 5<sup>th</sup> word or so) from a passage or sentence and then asking the reader/learner to supply the missing elements.



### 7.4 Identify the Theme or Sub Theme Tested

The Curriculum can be classified into the PISA framework as per the following specifications. Teachers can link the question asked with the concepts listed under each category.

CURRICULUM- CLASS VII-SCIENCE		
Physical Systems	Earth and Space Systems	Living Systems
<ul style="list-style-type: none"> <li>❖ Heat</li> <li>❖ Motion and Time</li> <li>❖ Electric Current and Its Effects</li> <li>❖ Light</li> <li>❖ Acids, Bases, and Salts</li> <li>❖ Physical and Chemical Changes</li> <li>❖ Water: A Precious Resource</li> <li>❖ Waste Water Story</li> </ul>	<ul style="list-style-type: none"> <li>❖ Weather Climate and Adaptation of Animals to Climate</li> <li>❖ Winds, Storms, and Cyclones</li> <li>❖ Soil</li> </ul>	<ul style="list-style-type: none"> <li>❖ Nutrition in Plants</li> <li>❖ Nutrition in Animals</li> <li>❖ Fibre to Fabric</li> <li>❖ Respiration in Organisms</li> <li>❖ Transportation in Animals and Plants</li> <li>❖ Reproduction in Plants</li> <li>❖ Forest: our Lifeline</li> </ul>

CURRICULUM- CLASS VIII-SCIENCE		
Physical Systems	Earth and Space Systems	Living Systems
<ul style="list-style-type: none"> <li>❖ Synthetic Fibres and Plastics</li> <li>❖ Materials—Metals and Non-Metals</li> <li>❖ Combustion and Flame</li> <li>❖ Force and Pressure</li> <li>❖ Friction</li> <li>❖ Sound</li> <li>❖ Chemical Effects of Electric Current</li> <li>❖ Light</li> </ul>	<ul style="list-style-type: none"> <li>❖ Some Natural Phenomena</li> <li>❖ Stars and Solar Systems</li> <li>❖ Coal and Petroleum</li> </ul>	<ul style="list-style-type: none"> <li>❖ Crop Production and Management</li> <li>❖ Micro Organisms-Friend or Foe</li> <li>❖ Conservations of Plants and Animals</li> <li>❖ Cell--Structure and function</li> <li>❖ Reproduction in Animals</li> <li>❖ Reaching the Age of Adolescence</li> <li>❖ Pollution of Air and Water</li> </ul>

CURRICULUM- CLASS IX-SCIENCE		
Physical Systems	Earth and Space Systems	Living Systems
<ul style="list-style-type: none"> <li>❖ Matter in our Surroundings</li> <li>❖ Is Matter around us Pure</li> <li>❖ Atoms and Molecules</li> <li>❖ Structure of the Atom</li> <li>❖ Motion</li> <li>❖ Force and Laws of Motion</li> <li>❖ Work and Energy</li> <li>❖ Sound</li> </ul>	<ul style="list-style-type: none"> <li>❖ Gravitation</li> <li>❖ Natural Resources</li> </ul>	<ul style="list-style-type: none"> <li>❖ The Fundamental Unit of Life</li> <li>❖ Tissues</li> <li>❖ Diversity in Living Organisms</li> <li>❖ Improvement in Food Resources</li> <li>❖ Why do We Fall Ill</li> </ul>





CURRICULUM- CLASS X-SCIENCE		
Physical Systems	Earth and Space Systems	Living Systems
<ul style="list-style-type: none"> <li>❖ Chemical Reactions and Equations</li> <li>❖ Acids Bases and Salts</li> <li>❖ Metals and Non-Metals</li> <li>❖ Carbon and its Compounds</li> <li>❖ Periodic classification of Elements</li> <li>❖ Electricity</li> <li>❖ Magnetic Effects of Electric Current</li> <li>❖ Light</li> <li>❖ Human Eye and the Colourful World</li> </ul>	<ul style="list-style-type: none"> <li>❖ Management of Natural Resources</li> <li>❖ Sources of Energy</li> </ul>	<ul style="list-style-type: none"> <li>❖ Life Processes</li> <li>❖ Control and Coordination</li> <li>❖ How do Organisms Reproduce</li> <li>❖ Heredity and Evolution</li> <li>❖ Our Environment</li> </ul>

Besides the Physical Systems, Earth and Space and Living Systems, Technology Systems are an other significant content areas in PISA. Although a specific chapter on Technology Systems is not a part of the science curriculum, we know very well that science and technology are closely linked in a complementary way. If we look at our curriculum as an integrated whole, we do span a whole range of technological aspects that impact scientific advancements as well as our lives. It follows then, that teachers must sensitize students to the same and prepare them adequately.

### 7.5 Identify Strategy/Strategies for Teaching the Specific Concept

(Refer to Chapter 4)

(Cross-curricular Linkages are also possible in the curriculum)

**What are cross-curricular linkages?** A sensitivity towards and a synthesis of knowledge, skills, and understanding from various subject areas.

**Why are they important?** Inter-disciplinary teaching can increase students' motivation for learning and their level of engagement. Students will be able to make meaningful and relevant connections between disciplines.

**How can subject areas be linked?** Disciplines may be related or integrated through a central theme, issue, problem, process, topic or experience.



An Example of Cross-Curricular Linkages is given below:

**ENGLISH AND SCIENCE**

Class IX-English-Chapter 10 titled Kathmandu has a component on Flute. Every flute produces music with the help of human breath.

Class VIII-Science-Chapter 13- The Chapter on Sound can be linked with the English chapter titled Kathmandu.

**SCIENCE AND MATH**

Class VIII- Mathematics  
Chapter 5—Data Handling –Graphical representation of sound waves

**SCIENCE AND ART**

**CROSS-CURRICULAR LINKAGES**

Chapter  
**13** SOUND



How do you come to know that a 'period' is over in your school? You come to know easily that someone is at your door when they knock or you hear the sound of the doorbell. Most of the time you can make out that someone is approaching you by just hearing the foot steps.

Sound plays an important role in our lives. It helps us to communicate with one another. We hear a variety of sounds in our surroundings.

Make a list of sounds you hear in your surroundings. In the music room of your school, listen to the sounds produced by musical instruments like flute, tabla, harmonium etc.

You might have also played a game called hide and seek. How is sound produced? How does it travel from one place to another? How do we hear remaining players. How is the sounds? Why are some sounds louder than others? We shall discuss such questions in this chapter.

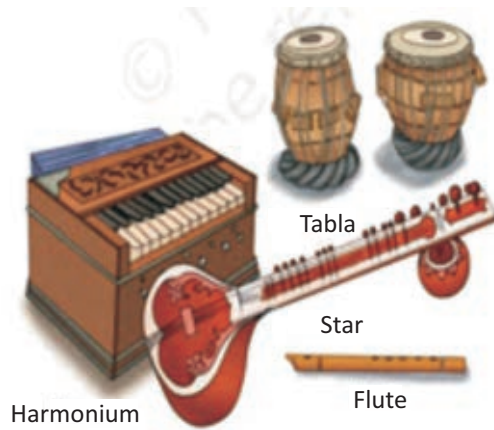


Figure 16: Some Musical Instruments

Given below are two examples of mapping of two published PISA questions: .

**Mapping-Example 1**

**The greenhouse effect: fact or fiction?**

Living things need energy to survive. Energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth. The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an air less world.

Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs

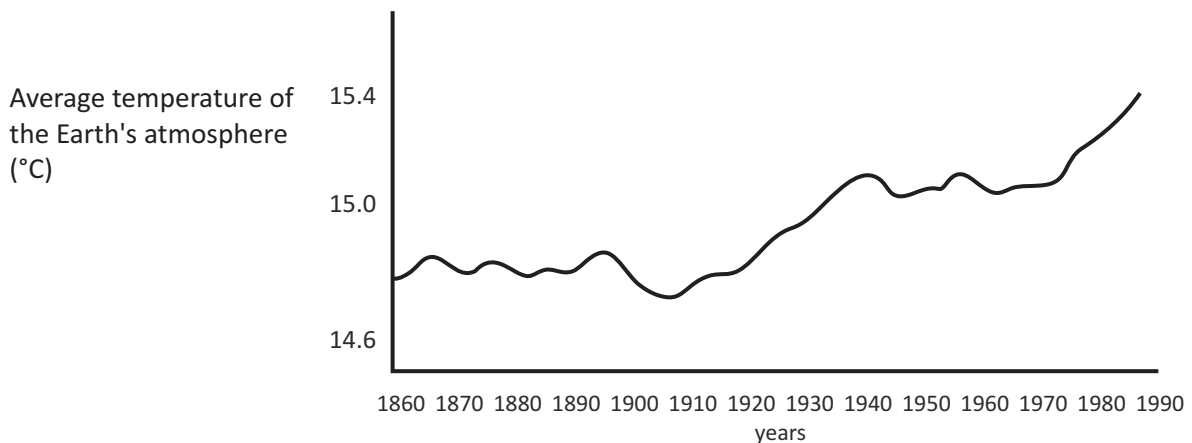
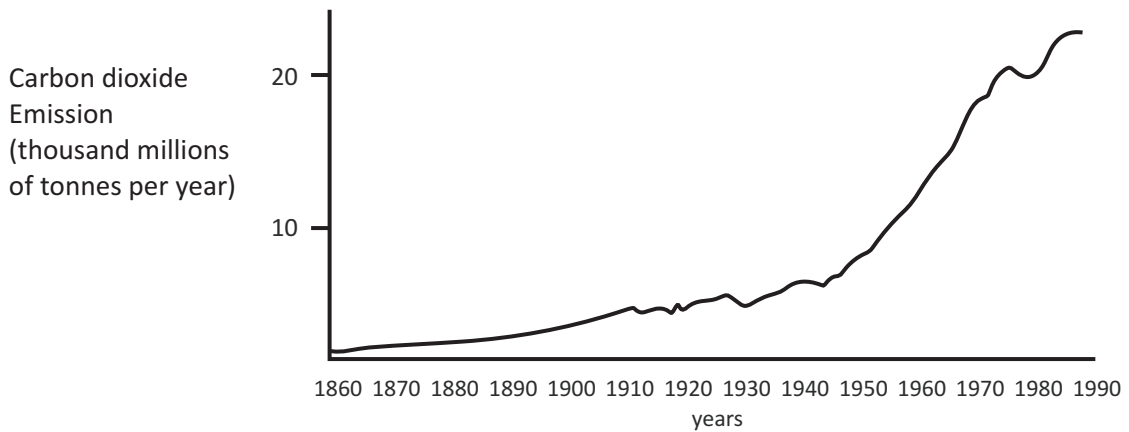




some of this energy, while some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere. As a result of this, the average temperature above the Earth's surface is higher than it would be if there was no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term green house effect.

The greenhouse effect is said to have become more pronounced during the twentieth century. It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals, the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century. A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

**In a library, he comes across the following two graphs.**



**Source: CSTI Environmental Information Paper 1, 1992.**



André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

**QUESTION 1**

What is it about the graphs that supports André's conclusion?

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**QUESTION 2**

Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion. Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

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**QUESTION 3**

André persists in his conclusion that the average temperature rise of the Earth's atmosphere is caused by the increase in the carbon dioxide emission. But Jeanne thinks that his conclusion is premature. She says: "Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant". Name one of the factors that Jeanne means.

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**Mapping:**

<b>Classes</b>	<b>VII-IX</b>
<b>Level</b>	<b>Moderate Proficiency</b>
<b>Unit/ Concept</b>	<b>Environment (Greenhouse Effect)</b>
<b>Theme</b>	<b>Earth Sciences</b>
<b>Item Type</b>	<b>Question 1- Closed Constructed Response</b> <b>Question 2-Open Constructed Response</b> <b>Question 3-Open Constructed Response</b>
<b>Typology</b>	<b>Understanding</b>
<b>Strategy</b>	<b>Experiential Method</b>

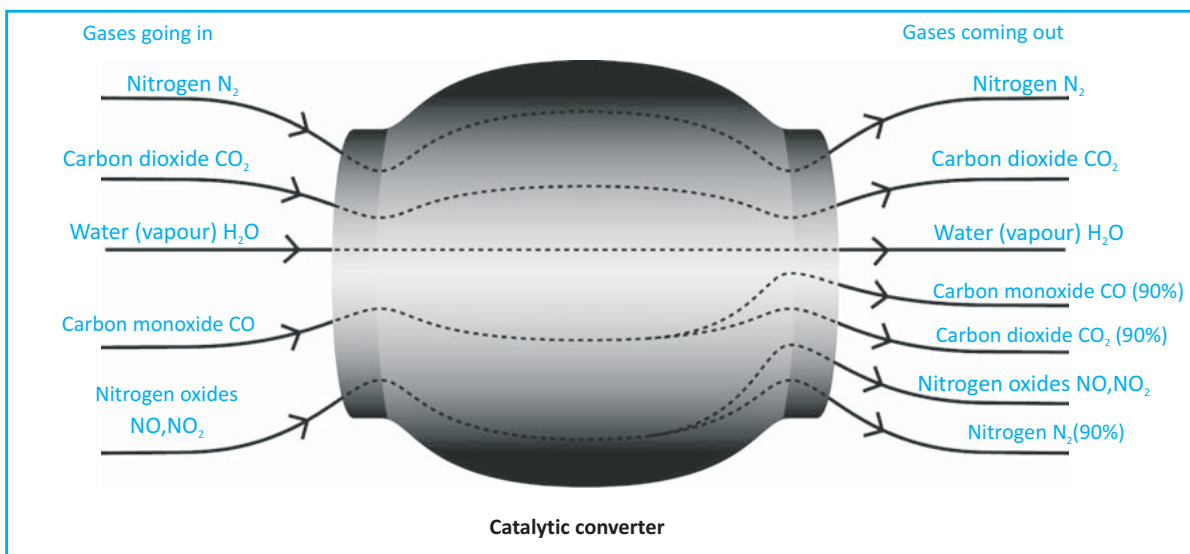




## Mapping-Example 2

### Catalytic Converter

Most modern cars are fitted with a catalytic converter that makes the exhaust fumes of the car less harmful to people and to the environment. About 90% of harmful gases are converted into less harmful ones. Here are some of the gases that go into the converter and how they come out of it.



#### Question 1

Use the information in the diagram above to give an example of how the catalytic converter makes exhaust fumes less harmful.

.....

#### Question 2

Changes take place to gases inside the catalytic converter. Explain what is happening in terms of *atoms* and *molecules*.

.....

.....

#### Question 3

Examine the gases emitted by the catalytic converter. What is one problem that engineers and scientists working on the catalytic converter should try to solve to produce less harmful exhaust fumes?

.....

.....



Question 4 (Attitude)

How much do you agree with the following statements? Tick only one box in each row.

	Strongly Agree	Agree	Disagree	Strongly Disagree
Knowing how car fuels differ in the amounts of toxic fumes they produce				
Understanding more about what happens inside a catalytic converter				
Learning about vehicles that do not emit toxic exhaust or fumes				

Mapping

<b>Class</b>	<b>IX</b>
<b>Level</b>	<b>High Proficiency</b>
<b>Unit/Concept</b>	<b>Catalytic Converter</b>
<b>Theme</b>	<b>Physical Sciences</b>
<b>Item type</b>	<b>Question 1- Closed Constructed Response</b> <b>Question 2- Closed Constructed Response</b> <b>Question 3- Closed constructed response</b> <b>Question 4- Multiple Choice Question</b>
<b>Typology</b>	<b>Understanding and Application</b>
<b>Strategy</b>	<b>Experiential Method/Cooperative Learning</b>

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# CHAPTER 8

## ASSESSMENT AS A TOOL



In education, the term assessment refers to the wide variety of methods or tools that educators use to evaluate, measure, and document the academic readiness, learning progress, skill acquisition, or educational needs of students. Hence, it is an essential component of the teaching-learning processes. It assesses both teacher effectiveness and learning outcomes.

**Points to Ponder**

- Have I ever assessed my students on their ability to perform an experiment individually or in a group?
- Which activities can help me in assessing my students on an indicator like 'teamwork'?
- Whether the learning outcome has been achieved?

### 8.1. Assessment- Why?

At the end of every lesson, the teacher has to find out-

- ✓ What went well?
- ✓ How can I improve upon the lesson?
- ✓ What would I change if I had to teach the lesson again?

Reflecting on the above questions can help the teacher devise assessment strategies to improve his/her own work. In short, reflection helps a teacher to devise assessment tools.

Assessment tools devised by teachers on the basis of their reflection can help students in knowing:

- ✓ What is important to learn ?
- ✓ What have I learned/not learned ?
- ✓ Where and How to improve ?

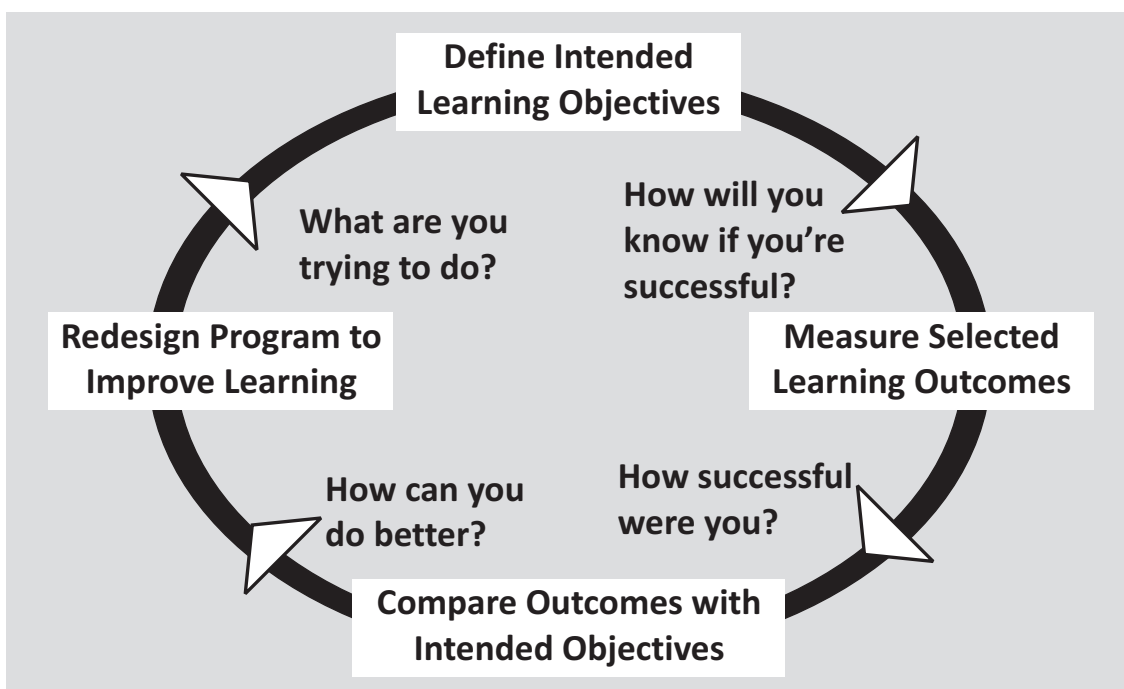


Figure 17: Assessment Learning Cycle



According to 'Source Book on Assessment' by NCERT in Science, assessment should focus on whether the child has learned the following:

• **Observation:** Has the child observed a phenomenon accurately or superficially?

• **Experimentation:** Has the learner skillfully planned and performed an experiment or activity? Was the learner able to handle the material and equipment properly?

• **Measurement:** Was the learner able to take and tabulate the readings accurately?

• **Analysis and Interpretation:** Did the learner use reason for analysing the results of the experiment and interpret them correctly?

• **Communication:** Did the learner express the outcome in an organised way?

• **Creativity:** Did the learner exhibit innovativeness and creativity in planning the activities?

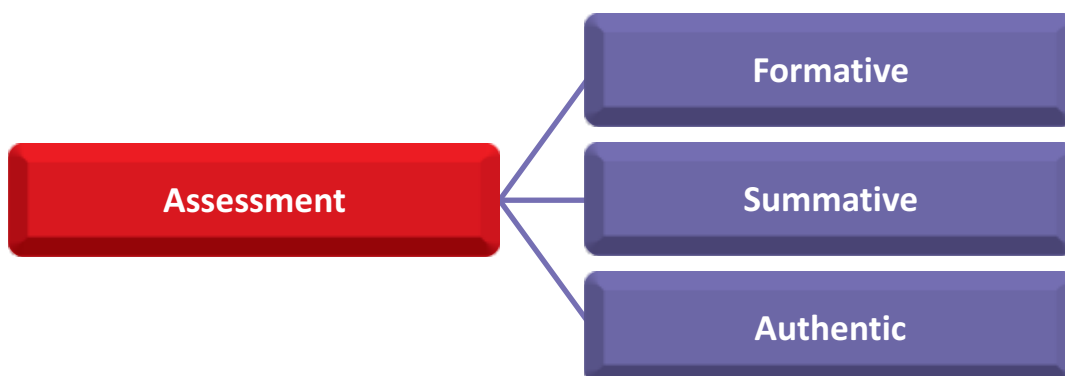
Traditionally, assessment is done through paper-pen tests or written tests. These tests give quantitative scores or achievement levels that may not be reflective of actual learning which has taken place. Such an assessment does not help a teacher to reflect upon his/her performance to improve his/her teaching.

Alternative tools of assessment do a more systematic assessment of learners' abilities as various methods are used to collect data about learners' achievement and their work is analysed, feedback is given so that the learner can take responsibility for his/her learning.

### 8.2. Assessment- How?

Assessment is integral to the teaching-learning process, facilitating students' learning, improving instruction, and can take a variety of forms. To create a balanced assessment approach in teaching-learning, different types of assessment strategies should be incorporated.

Assessment can be of three types- assessment for learning (formative assessment), assessment of learning (summative assessment) and assessment as learning (authentic assessment).





- **Assessment for Learning (Formative Assessment)** - In this form of assessment, a teacher embeds various forms of assessment all through the teaching and learning process. Therefore, it is an ongoing assessment that allows teachers to monitor students on a day-to-day basis and modify their teaching based on what the students need to be successful. This assessment provides students with timely, specific feedback that they need, to make adjustments to their learning.
- **Assessment of Learning (Summative Assessment)**- Assessment of learning is the snapshot in time that lets the teacher, students and their parents know how well the student has grasped the learning outcomes of a module or programme, and which contributes to the final mark given for the module/ lesson. This form of assessment is typically held at the end of a teaching learning process and is often referred to as summative assessment.
- **Assessment as Learning (Authentic Assessment)** - Assessment as learning is typically a self-assessment by students to gauge their own levels and gaps in learning and is crucial in helping students become life-long learners. This assessment can also be called as a work-related assessment where the tasks and conditions are more closely aligned to what is experienced in real life. This form of assessment is designed to develop students' skills and competencies alongside academic development.

### 8.3. Why Authentic Assessment?

So far, formative and summative assessments are used by our teachers that test what the students have learned in school. However the purpose of education is that student should be able to use the acquired knowledge and skills in real-world. For example, a teacher may instruct students on how to use an email program, including how to compose an email, edit it, and send it. Rather than offering a multiple-choice test about the email program, the teacher may choose to evaluate his/her students' understanding of email by requiring them to compose and send an email to him/her describing what email is and the benefits of using it at school. This approach provides an authentic assessment of the students' learning.

An authentic assessment tells the students if they are ready to apply what they have learned in authentic situations. It is one way to determine what students can actually do and whether they are developing the competencies that will be expected of them when they leave school.

Traditional Assessment	Authentic Assessment
Selecting a Response	Performing a Task
Contrived	Real Life
Recall/ Recognition	Construction/ Application
Teacher-Structured	Student-Structured
Indirect Evidence	Direct Evidence

Figure 18: Traditional Assessment vs. Authentic Assessment

Given below are some tasks that can be used for authentic assessment-

- a) **Performance of Tasks**- When students perform tasks before an audience for example: teachers, peers, community members, and/or experts to show what they know and what they are able to do, it is an authentic assessment of what they have learned. This audience evaluates the quality of performance with the help of some rubrics.





Some examples of performance assessment in science are-

- ✓ Explaining historical events related to science
- ✓ Generating scientific hypothesis
- ✓ Solving numerical problems based on scientific formulae
- ✓ Deciphering scientific text in other languages
- ✓ Creating a model based on theories/ hypothesis discussed in class
- ✓ Describing research conducted on an assigned topic

**b) Extended Tasks-** Extended tasks are assignments that require sustained attention and last for several hours. Such tasks may include writing, editing, and revising an essay or story; designing a machine; conducting and describing the results of a science experiment; or building a scale model. Once again, what is valuable is that students demonstrate what they know and can do. Depending on the task, the teacher, student peers, community members, or experts evaluate the work, usually with the help of a rubric.

**c) Portfolios-** Portfolios are collections that bring all types of work- physical or virtual-in one place. Portfolios may contain:

- ✓ Elements that document student performances (such as slides from an oral presentation)
- ✓ Written products
- ✓ Self-reflections on the quality of various products
- ✓ Documentation of the processes by which these products were completed
- ✓ Others' evaluations of the products

Like performance assessment and extended tasks, portfolios are typically graded with a rubric and can be evaluated by the teacher, student peers, community members, and/or experts.

**8.3 Devising a Strategy for Authentic Assessment-** Authentic assessment requires a judgment of quality. Hence, the teacher must consider the following:

- Assign authentic tasks that are analogous to real-world challenges.
- The tasks must have the scope of evaluating the meaningful application of knowledge and skills.
- A wise combination of authentic and traditional assessment can be devised.
- Rubrics must be used to evaluate authentic tasks.

#### **8.4. Assessment using Rubrics**

Rubrics for assessment is a tool used to interpret and grade students' work against criteria and standards. Rubrics are sometimes called 'criteria sheets', 'grading schemes', or 'scoring guides'. These can be designed for any content domain and are usually in the form of a matrix or grid.

Students must be made familiar with rubrics so that they know what is expected of them and then they take more responsibility of their learning. Rubrics can be employed during peer assessment and self-assessment too.

**Assessment rubrics have the following three elements:**

- A set of criteria that provides an interpretation of the stated objectives (performance, behaviour, quality).
- A range of different levels of performance between the highest and the lowest.
- Descriptors that specify the performance corresponding to each level, to allow assessors to interpret which level has been met.



## Sample Rubrics for Evaluating Lab Reports

CRITERIA	4	3	2	1
<b>Scientific Concepts</b>	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.
<b>Procedures</b>	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment
<b>Drawings/Diagrams</b>	Clear, accurate diagrams are included and make the experiment easier to understand. Diagrams are labelled neatly and accurately.	Diagrams are included and are labelled neatly and accurately.	Diagrams are included and are labelled.	Needed diagrams are missing OR are missing important labels.
<b>Analysis</b>	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.
<b>Handling of Materials/ Equipment</b>	All materials and setup used in the experiment are clearly and accurately described.	Almost all materials and the setup used in the experiment are clearly and accurately described.	Most of the materials and the setup used in the experiment are accurately described.	Many materials are described inaccurately OR are not described at all.
<b>Practical Notebook</b>	Clear, accurate, dated notes are taken regularly.	Dated, clear, accurate notes are taken occasionally.	Dated, notes are taken occasionally, but accuracy of notes might be questionable.	Notes rarely taken or of little use.

### 8.5. Strategies for Learning from Assessment

There are several techniques/ strategies of assessment that enhance learning. Some of them are:

- a) **Reflection by the students-** Reflection is about students becoming aware of their thinking processes, and being able to make those transparent to others. It enables assessment of the 'why' and 'how' of learning, and what needs to be done as a result. When students and teachers routinely reflect they will be able to easily describe:
- i) what is intended to be learned ?
  - ii) where they have got to go ?
  - iii) the learning process.
  - iv) where they will go next ?
  - v) the learning culture in the classroom.



- b) **Self and Peer Assessment-** Self and peer assessment is about revision and improvement. It enables students to independently assess their own and other students' progress with confidence rather than always relying on teacher judgment. When students self and peer assess, they are actively involved in the learning process and their independence and motivation is improved.
- c) **Effective Feedback-** Specific, descriptive feedback is necessary for improvement and success. Teachers who combine strong subject knowledge with effective feedback can offer students rich, focused information about their learning and how to improve it.
- d) **Strategic Questioning-** Open-ended questions make students grasp ideas in class. These questions reveal more what students have learned. High order questions such as 'why' and 'how' help the teacher discern the level and extent of the students' understanding.
- e) **Summarising-** Ask the students to summarise or paraphrase important concepts and lessons. This can be done orally, visually, or otherwise. Through summarising, students learn how to discern the most important ideas in a text, how to ignore irrelevant information, and how to integrate the central ideas in a meaningful way.

While the idea of teaching critical thinking has been canvassed around in education circles since the time of John Dewey, it has taken greater prominence in the education debates with the advent of the term '21st century skills' and discussions of deeper learning. There is increasing agreement among education reformers that critical thinking is an essential ingredient for long-term success for all of our students.

Given the increasing emphasis on preparing students for the future knowledge society, the assessment paradigms are continually being renewed and revised. It is imperative that as teachers we are sensitive to the need to assess critical thinking and creative thinking skills to check whether we are preparing children for life and for real-life situations. The PISA assessment frameworks and instruments are being used as the best practice models for improving national assessments; many countries have explicitly incorporated and emphasized PISA-like competencies in revised national standards and curricula; others use PISA data to complement national data and validate national results against an international benchmark.

*Science literacy is the artery through which the solutions of tomorrow's problems flow.*

*Neil de Grasse Tyson*

*I would teach how science works as much as I would teach what science knows. I would assert that science literacy is the most important kind of literacy (we) can take into the 21st century. I would undervalue grades based on knowing things and find ways to reward curiosity. In the end, it's the people who are curious who change the world.*

*Neil deGrasse Tyson*



## 8.6 Summary descriptions of the seven proficiency levels on the scientific literacy scale

Level	What students can typically do
6	At Level 6, students can draw on a range of inter related scientific ideas and concepts from the physical, life and Earth and space sciences and use procedural and epistemic knowledge to offer explanatory hypotheses of novel scientific phenomena, events, and processes that require multiple steps or to make predictions. In interpreting data and evidence, they are able to discriminate between relevant and irrelevant information and can draw on knowledge external to the normal school curriculum. They can distinguish between arguments that are based on scientific evidence and theory and those based on other considerations. Level 6 students can evaluate competing designs of complex experiments, field studies or simulations and justify their choices.
5	At Level 5, students can use abstract scientific ideas or concepts to explain unfamiliar and more complex phenomena, events and processes. They can apply more sophisticated epistemic knowledge to evaluate alternative experimental designs and justify their choices and use theoretical knowledge to interpret information or make predictions. Level 5 students can evaluate ways of exploring a given question scientifically and identify limitations in interpretations of data sets including sources and the effects of uncertainty in scientific data.
4	At Level 4, students can use more sophisticated content knowledge, which is either provided or recalled, to construct explanations of more complex or less familiar events and processes. They can conduct experiments involving two or more independent variables in a constrained context. They are able to justify an experimental design, drawing on elements of procedural and epistemic knowledge. Level 4 students can interpret data drawn from a moderately complex data set or less familiar contexts and draw appropriate conclusions that go beyond the data and provide justifications for their choices.
3	At Level 3, students can draw upon moderately complex content knowledge to identify or construct explanations of familiar phenomena. In less familiar or more complex situations, they can construct explanations with relevant cueing or support. They can draw on elements of procedural or epistemic knowledge to carry out a simple experiment in a constrained context. Level 3 students are able to distinguish between scientific and non-scientific issues and identify the evidence supporting a scientific claim.
2	At Level 2, students are able to draw on every day content knowledge and basic procedural knowledge to identify an appropriate scientific explanation, interpret data, and identify the question being addressed in a simple experimental design. They can use every-day scientific knowledge to identify a valid conclusion from a simple data set. Level 2 students demonstrate basic epistemic knowledge by being able to identify questions that could be investigated scientifically.
1a	At Level 1 a, students are able to use every-day content and procedural knowledge to recognize or identify explanations of simple scientific phenomenon. With support, they can undertake structured scientific inquiries with no more than two variables. They are able to identify simple causal or correlational relationships and interpret graphical and visual data that require a low level of cognitive demand. Level 1 a students can select the best scientific explanation for given data in familiar personal, local and global contexts.
1b	At Level 1b, students can use every-day content knowledge to recognize aspects of simple scientific phenomenon. They are able to identify simple patterns in data, recognize basic scientific terms and follow explicit instructions to carry out a scientific procedure.



## 9. A Note for all Teachers: The Game Changers

PISA—an opportunity, not a burden!

PISA 2021—Let's look forward to it with the necessary optimism and preparedness.

With the country's commitment to PISA and the students of Chandigarh/KVS/NVS being a sample, teachers are expected to participate in a series of training programmes and workshops to reorient themselves. They are also expected to prepare diverse tools and tests for ongoing assessments, engage more with students, assess them more frequently and authentically, and analyze their work periodically.

Education is not a preparation for life; it is life itself. At the end of their school education, all our students should be informed young citizens equipped with the 3 Hs (Heds-on, Hands-on and Hearts-on) to confront the challenging tests of life. Opportunities must be created and systematic training in 21<sup>st</sup> century skills of critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity and social skills must be imparted to ensure that students learn to apply them in authentic situations that address real-world problems and issues.

The outstanding Board Examination results of students of Union Territory of Chandigarh, Kendriya Vidyalayas and Navodaya Vidyalayas are a testimony to the sincere efforts that teachers have been putting into their work. Although they are already intensively involved in planning their lessons, evolving the best strategies to teach, developing resources and assessing their learners, the need of the hour is to realign their goals to a new thought process, as encapsulated in the objectives of PISA. The child in your hands has to traverse an upward path from mere mastery of content to the realm of creative and critical thinking; from content to context, in order to be able to take on real-life challenges.

It is essential to re-invent ourselves from time to time. What is it that we can change in the way we teach, and the way our students learn, so that teaching becomes rewarding and learning becomes joyful and stress-free for children? We need to evaluate our system of education and adopt the best practices to be able to compete in the globally and digitally interconnected world and have a cutting edge over others. It is important to transform our younger workforce into a more creative and productive one and this can be done by providing quality education in all parts of the country.

PISA's focus on young people's ability to use their knowledge and skills to meet real-life challenges rather than merely mastering a specific school curriculum is certainly the objective towards which we all aspire. Instead of getting intimidated by the internationally accepted PISA benchmarking and assessment process, we must consider it as a positive and progressive step forward that will help us administer a reality check on our education system and reengineer it to the emerging challenges. All we have to do is to bridge the gap between the skills that students learn in the classrooms and the ones they will need to participate fully in a knowledge-based society.

Effecting a transformational change in students' learning experiences to match them with global standards is the responsibility of all academicians. The teachers in the classroom are the privileged ones for they get to participate in this immense task of nation-building; they are the ones to herald the advent of a renewed consciousness that would empower students to contribute constructively to the spectrum of the future society.

**The future of the world is in my classroom today. -Ivan Welton Fitzwater**



## 10. Further Study Resources

1. Anil Ananthaswamy      The Edge of Physics
2. Atul Gawande            Better  
                                    The Best American Science Writing
3. Bill Bryson                A Short History of Nearly Everything
4. Carl Sagan                Cosmos
5. Dava Sobel                The Planets
6. George Orwell            1984
7. Jared Diamond            Guns, Germs and Steel  
                                    The Rise and Fall of the Third Chimpanzee
8. Jayant Narlikar            From Black Clouds to Black Holes  
                                    Seven Wonders of Cosmos
9. John Holt                 How children Fail
10. Joanna Cole              The Magic School Bus Series
11. Jules Verne              Journey to the Centre of the Earth
12. Mary Roach              Packing for Mars: The Curious Science of Life in the Void
13. Sidharth Mukherjee      Emperor of all Maladies
14. Simon Singh             Big Bang—The Origin of Universe
15. Stephen Hawking        A Brief History of Time
16. Yuval Noah Harari        Sapiens and Homo Deus

### Online Science Journals

- ❖ QuantaBest For: Intelligent people striving for scientific literacy
- ❖ MassiveBest for: The scientifically curious
- ❖ National Geographic Best For: Everyone
- ❖ WiredBest For: Enlightened tech geeks
- ❖ CosmosBest For: Science lovers with varied interests
- ❖ NatureWorld’s leading multidisciplinary Science Journal

### Popular Science Magazines

- ✓ Science Reporter
- ✓ Dataquest
- ✓ Down to Earth
- ✓ National Geographic Kids
- ✓ Resonance
- ✓ Dream 2047



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- Curriculum for PLI, OEF
- <http://rubistar.4teachers.org>- website title - Create your Rubric
- NCERT. (2012). Source Book on Assessment for classes VI-VIII-Science (Page17). National Council of Education Research and Training, New Delhi
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- Sample rubrics on lab report-Create Your Rubric-Customize Your Rubric Retrieved August 06, 2019, from [http://rubistar.4teachers.org/index.php?screen=CustomizeTemplate&bank\\_rubric\\_id=26&on\\_is=4&](http://rubistar.4teachers.org/index.php?screen=CustomizeTemplate&bank_rubric_id=26&on_is=4&)
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केन्द्रीय माध्यमिक शिक्षा बोर्ड

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