TEACHER'S HANDBOOK FOR PISA 2021- SCIENCE
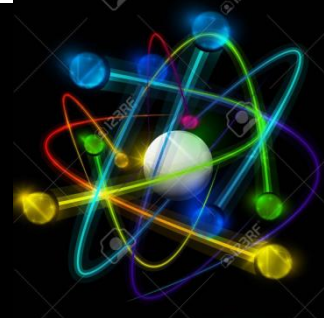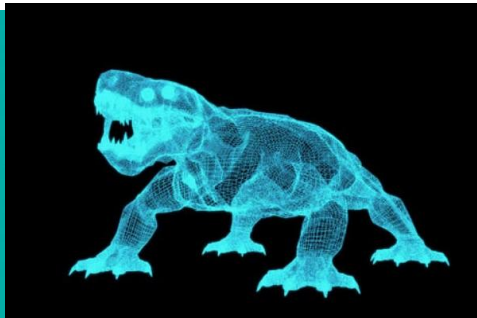
TABLE OF CONTENTS

Foreword:

It is imperative for any progressive and successful economy to align its educational goals with the larger global goals. This would mean that the future citizens must be equipped with the knowledge and skills that help them achieve their full potential as well as help them be global citizens.

Of primary importance, however is the need to have citizens with a scientific temper. We must ensure that the young citizens understand their local issues in the light of their context. In view of this, the quantum of time spent in schools has to be meaningfully utilized in a manner, that it prepares students to become citizens who are confident and aware of the local context and who can then graduate to global thinking. The initial focus clearly is to create locally responsible citizens.

Since its inception in 2000, PISA, the OECD Programme for International Student Assessment has become a premier global benchmark for evaluating the quality, fairness and efficacy of school systems.

The evidence base that PISA produces goes well beyond statistical benchmarking. By identifying the characteristics of high-performing education systems, PISA allows governments and educators to identify effective policies that they can then adapt to their local contexts.

The PISA assessment in 2021 shall focus on the cognitive domain of Mathematical Literacy, an interdisciplinary language and tool-- a discipline that plays an all- pervasive role in our economic and social lives, in understanding societal progress as well development. It is an important component of learning and "doing" or using one's knowledge.

It is pertinent to mention here that Scientific Literacy will form a significant 50% of testing in PISA IN 2021. Science is a part of every aspect of our lives and is not just the domain of scientists. In the context of massive information flows and rapid change, everyone now needs to be able to "think like a scientist": to be able to evaluate evidence and come to a rational conclusion; to understand that scientific "truth" may change over time, as new discoveries are made, and as humans develop a greater understanding of natural forces and of technology's capacities and limitations.

Each passing year catapults us into the realm of new scientific discoveries. From human cell regeneration for growing organs, to banishing genetic disease through breakthrough gene-editing techniques and recycling orbital rockets, scientific advances have transformed our economic and social life and made lives safer, easier and more enjoyable. We can claim to successfully have developed scientific temper in the larger sense if we understand and recognize science to be a mere tool and as aware citizens take the call to use scientific advancements responsibly, constructively and creatively.

Against this backdrop, all stakeholders need to reconstruct and conceptualize a plan towards success and excellence in PISA 2021.Let us aim for an education that empowers our children with the requisite competencies for a cutting edge global presence.

Chapter 1- INTRODUCTION

1.1.   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**

> **Background**
> - **PISA—PM's 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.**
> - **OECD has agreed to tweak the test questions to the Indian context.**

which **aims to evaluate education systems** **worldwide** by testing the skills and knowledge of 15-year-old students who are nearing 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.

1.2.   Why PISA--Objective

PISA, a competency based assessment, was 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, to allow them to compare how students in their countries were 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

> **Why PISA for India?**
> - **PISA—will help introduce competency based examination reforms in the school system.**
> - **Will discourage rote learning**
> - **Lead to recognition and acceptability of Indian students & prepare them for global economy of 21st Century.**

other countries' practices. It can help policy makers use the results of PISA to make decisions about education, to inform their teaching and set new targets.

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

Our current education 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 which will not only make our education more relevant for current times but also make it **Future Proof.** 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 educators and educatees.

1.3. PISA Procedure

Every three years, students complete an assessment including items testing **Reading literacy, Mathematical literacy and Scientific literacy.** In each cycle of PISA, **one of the cognitive areas** is the main focus of the assessment, with most of the items focusing on this area and fewer items on the other two areas. In addition to these three students are tested in an innovative domain such as collaborative problem solving in 2015 and global competence in 2018. Students also

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

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 of other countries.

1.4. 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.**
- **The focus will be Mathematical Literacy.**
- **In addition, students have an option of being tested in an innovative subject—Creative Thinking**

PISA 2021
5250 students (150 schools x 35 students) will be assessed on the following subjects:-
- **Maths and Science (47% students)**
- **Maths and Reading (47% students)**
- **Reading and Science (6%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

1.5.   The reporting 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?

1.5.   What do PISA students and schools do? -- Principles of Testing

II.   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
    - No guesswork
    - Answers are related to previous answers
- Participating students complete a **two-hour paper and-pen assessment.**

III.   Context questionnaire

- ✓ Data is collected through a 35-minute Student Questionnaire which provides an opportunity
    - to investigate factors that may influence performance and
    - give context to the achievement scores.

IV.   Background Questionnaire

- ✓ Responses to a set of 'core' questions about the student and their family background, (including age, year level and socio economic status) are collected during each assessment SEP

V. School Survey

- ✓ Information at the school-level is collected through a 30-minute online School Questionnaire, answered by the Principal
- ✓ The questionnaire seeks descriptive information about the school and information about instructional practices.
- ✓ The survey results provide rich context for the achievement data.

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 Schools students are not eligible.
- Students born between Jan 2005 to Feb 2006 as test will be held in April.

The Challenge Ahead

- ✓ India didn't appear in PISA in 2012 and 2015 on account of its dismal performance in 2009, when it was placed 72nd among the 74 participating countries.

- ✓ 2021--PISA will help reveal where India stands globally as far as learning outcomes are concerned.

- ✓ Speaking at the signing ceremony, HRD minister Prakash Javadekar said 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 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.

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Chapter 2- SCIENTIFIC LITERACY IN PISA

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."

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 on their lives.

2.1. What is Scientific Literacy?

Scientific literacy means:

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

(National Science Education Standards, page 22)

2.2. 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 enquiry) 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 knowledge that would be gained from the science curriculum and apply it in novel and real life situations.**

The 2015 Definition of Scientific Literacy

PISA defines scientific literacy as the ability to engage with science-related issues, and 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 the **competencies** to:

Evaluate and design scientific enquiry: 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 generisability of explanations

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 relate 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 (eg newspapers, journals, internet etc.)

Figure 1: The essential features of each of the three competencies

For the purposes of the PISA assessment, these competencies will only be tested using the knowledge that 15-year-old students can reasonably be expected to have.

2.3. 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

Knowledge
What they know about
- ✓ the natural world and technology (Knowledge of Science)
  - ❖ **Content**
- ✓ Science itself (Knowledge about Science
  - ❖ **Procedural**
  - ❖ **Epistemic**

Context
Life Situations that involve Science and Technology
- ✓ **Personal**
- ✓ **Local/National**
- ✓ **Global**

Requires people to →

Competencies
- ✓ **Explain Phenomena scientifically**
- ✓ **Interpret data and evidence scientifically**
- ✓ **Evaluate and design scientific enquiry**

← **How they do so is influenced by**

Attitudes
How they respond to Science issues:
- ✓ **Interest in Science**
- ✓ **Valuing Scientific approaches to enquiry**
- ✓ **Responsibility and awareness towards resources & environments**

Figure 2--The components of the PISA scientific literacy framework

Situations and Context

PISA´s orientation focuses on preparing students for their future lives, and so the **test items for the PISA science assessment are situated in general life**, 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 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.*

	Personal self, family and peer groups	Social the community Local/National	Global life across the world
Health	Maintenance of health, accidents, nutrition	Control of disease, social transmission, food choices, community health	Epidemics, spread of infectious diseases
Natural Resources	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 species
Environment Quality	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
Hazards	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
Frontiers for Science & Technology	Interest in science's explanations of natural phenomena, science based hobbies, sport 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

2.4. Scientific Competencies

The PISA scientific literacy assessment items requires 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 Knowledge of Science (knowledge about the natural world) and Knowledge about Science itself

Knowledge of Science

Clearly 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 are able to 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

Figure 4 shows the four content areas defined within *Knowledge of science*

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

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

II.   Living systems
- **Cells (eg structures and functions, DNA, plant and animal)**
- **Humans (eg health, nutrition, subsystems [ie digestion, respiration, circulation, excretion, and their relationship], disease, reproduction)**
- **Populations (eg species, evolution, biodiversity, genetic variation)**
- **Ecosystems (eg food chains, matter and energy flow)**
- **Biosphere (eg ecosystem services, sustainability)**

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

Figure 4: PISA categories of knowledge of science

2.5. Knowledge about Science

As well as *Knowledge of Science*, PISA assesses **Knowledge About Science**, for which the framework for scientific literacy defines two categories: The first of these is **"Scientific Enquiry",** which centres on enquiry as the central process of science and the various components of that process The second is "**Scientific Explanations",** which are the result of scientific enquiry.

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

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

> **Scientific Enquiry**
>
> - **Origin (eg. Curiosity, Scientific Questions)**
> - **Purpose (eg. to produce evidence that helps answer scientific questions, current ideas/models/theories guide enquiries)**
> - **Experiments-eg different questions suggest different scientific investigations, design**
> - **Data (eg. Quantitative [measurements], qualitative [observations])**
> - **Measurement (eg. inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures)**
> - **Characteristics of results (eg. empirical, tentative, testable, falsifiable, self-correcting)**

> **Scientific Explanations**
>
> - **Types (eg. hypothesis, theory, model, scientific law)**
> - **Formation (eg. existing knowledge and new evidence, creativity and imagination, logic)**
> - **Rules (eg. logically consistent, based on evidence, based on historical and current knowledge)**
> - **Outcomes (eg. new knowledge, new methods, new technologies, new investigation**

Figure 5. PISA categories of *Knowledge about Science*

2.6. Scientific Literacy Framework

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

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

Figure 6: Scientific Literacy Framework

Scientific Literacy—Levels
Levels – Depth of Knowledge 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 given various sources, develop a plan or sequence of steps to approach a problem.

Scientific Literacy-- The structure of the assessment SEP
Item response formats SEP

- 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 in order to

understand and answer the science items, the stimulus material uses language that is as clear, simple and brief as possible while still conveying 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

2.7. Distribution of items

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

- ❖ **Simple multiple-choice items**-- items calling for – selection of a single response from four options – 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 (the typical format in 2006) – selection of more than one response from a list
- ❖ **constructed-response items**- 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).

2.7. 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 kinds of tasks they would be expected to successfully complete. A student whose ability places them 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
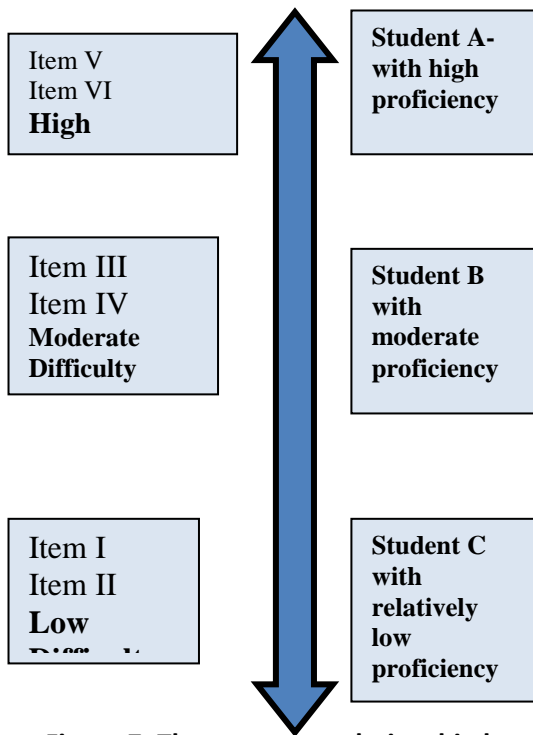
Item V Item VI **High**		Student A- with high proficiency	*It is expected that student A will be able to complete items I to V successfully, and probably item VI as well.*

Item III Item IV **Moderate** **Difficulty**		Student B with moderate proficiency	*It is expected that student B will be able to complete items I, II and III successfully, will have a lower probability of completing item IV and is unlikely to complete items V and VI successfully.*

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Item I Item II **Low** **Difficult**		Student C with relatively low proficiency	*It is expected that student C will be unable to complete items II to VI successfully, and will also have a low probability of completing item I successfully*

Figure 7: The relationship between items and students on the scientific literacy scale

2.8. Suggestions for Teaching

- **Engage your students in each task in the document as a whole-class discussion or by asking students to attempt a task and then discussing it afterward 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.**

PISA believes that every individual should be able to think scientifically about the evidence 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 situations to answer questions and make decisions about the natural world. The student is required to use knowledge that would be gained from the science curriculum and apply it in a novel situation.
The next two chapters will give you in an insight into the kind of questions that students are expected to solve.

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CHAPTER 3- ATTITUDES, ENGAGEMENT, AND MOTIVATION

Ideally, the purpose of teaching science is teaching students how to think, learn, solve problems and make informed decisions. But, students think of science as a subject isolated from humanity. To dispel these ideas, it is essential for teachers to understand the attitudes, engagement and motivation of students in learning science. Since the definition of scientific literacy in PISA also includes attitudes along-with context, knowledge, and competencies, it is important to assess the attitudes of students towards science. The following figure shows the relationship between these four aspects:
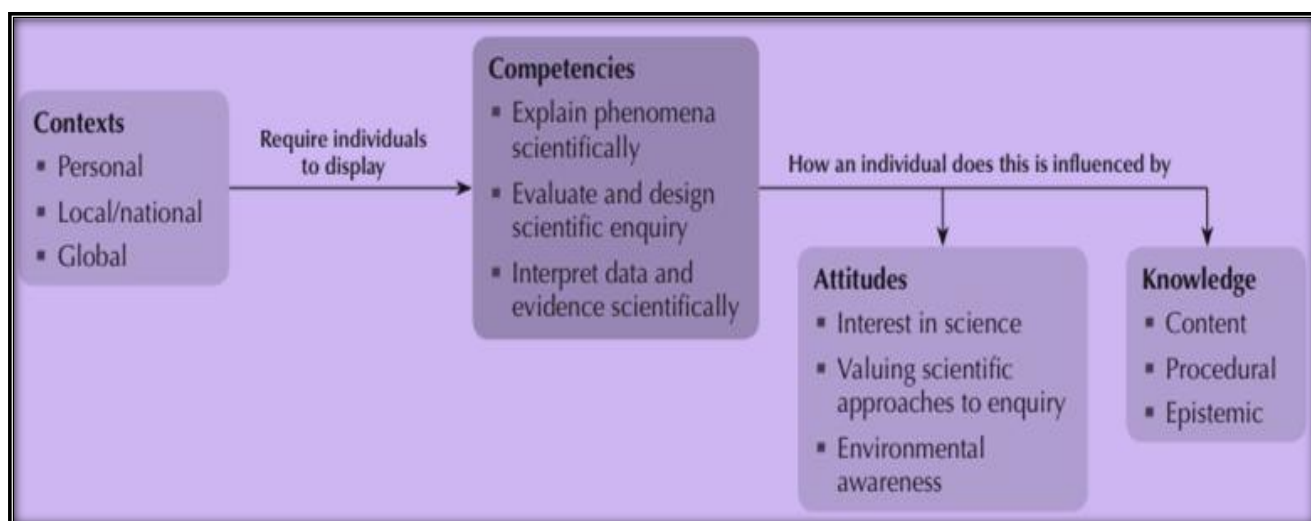
Figure 1: Inter-relations between the four aspects of scientific literacy

3.1. Scientific Constructs

Scientific literacy in PISA focuses on attitudes, interest, personal beliefs and engagement of a 15-year old student in relation to science. The following four areas (scientific constructs), namely, support of scientific enquiry, students' belief about learning science, interest, engagement in science, and responsibility towards resources and environments; provide an understanding of students' general appreciation and attitude towards science.

Support for scientific enquiry

- Students show they can
- Acknowledge the importance of considering different scientific perspectives and arguments.
- Support the use of factual information and rational explanations.
- Express the need for logical and careful processes in drawing conclusions.

Students' Beliefs and Learning Science

- Students believe they can
- Handle scientific tasks effectively.
- Overcome difficulties to solve scientific problems.
- Demonstrate strong scientific abilities.

Interest, engagement and motivation in science

- Students show that they:
- Indicate curiosity in science and science-related issues and endeavours.
- Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods.
- Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science related careers.

Responsibility towards resources and environments

- Students show they can:
- Show a sense of personal responsibility for maintaining a sustainable environment.
- Demonstrate awareness of the environmental consequences of individual actions.
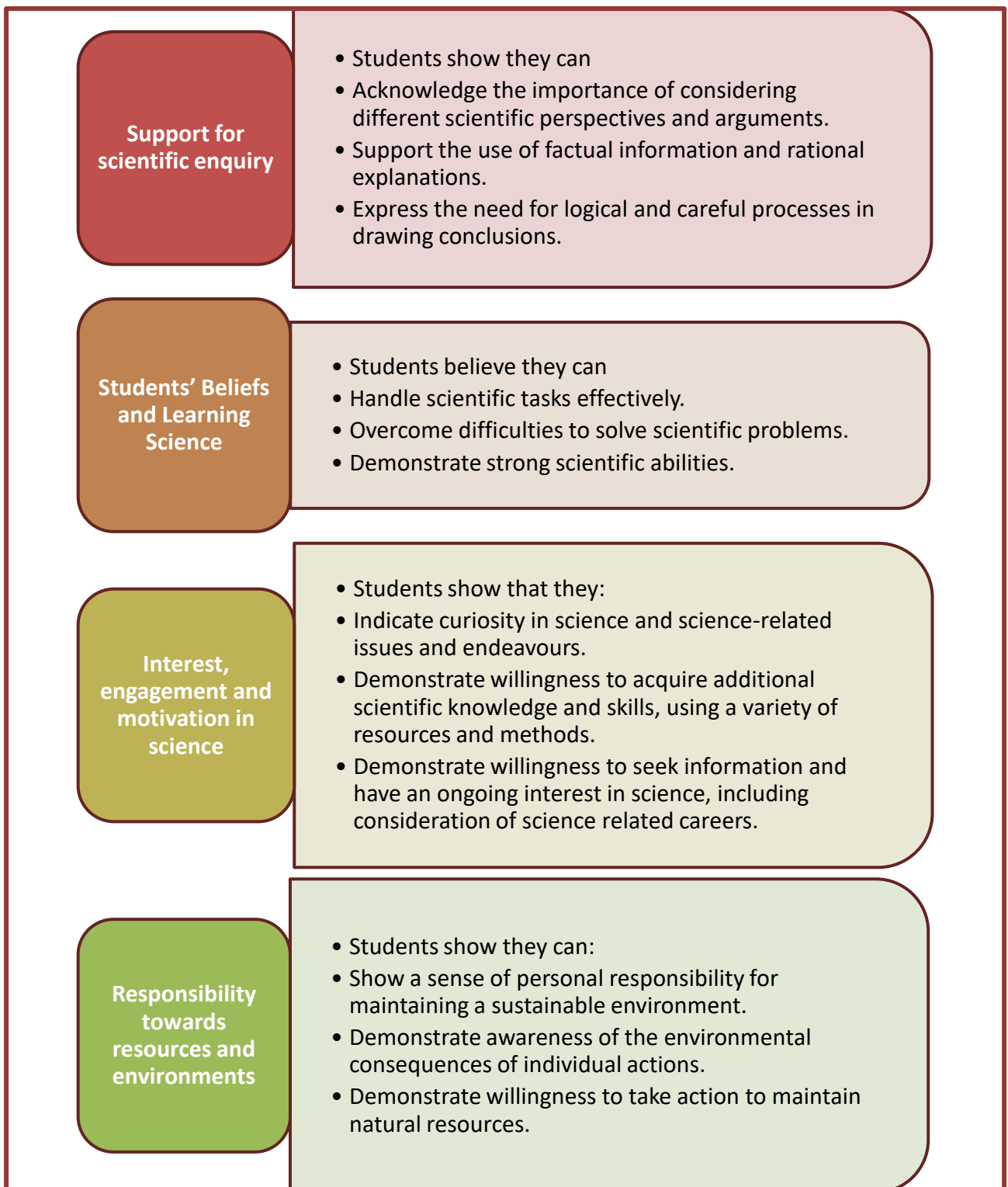- Demonstrate willingness to take action to maintain natural resources.

Figure 2- Scientific Constructs

Students' attitude towards science is associated with their expectations of future study and work in science and technology related fields, particularly among students who are highly proficient in science.

Teachers have a major role in shaping students' attitude towards science. The above scientific constructs can be developed in classrooms by engaging the students in thought-provoking assignments and discussions.

Support for Scientific Enquiry

General Value of Science

A strong general value of science relates to students valuing the contribution of science and technology, for understanding the natural and constructed world, and for the improvement of natural, technological and social conditions of life. Teachers can make students comprehend general value of science by discussing:

- ❖ Advances in science and technology usually improve people´s living conditions.
- ❖ Science is important for helping us to understand the natural world.
- ❖ Advances in science and technology usually help improve the country.
- ❖ Science is valuable to society.
- ❖ Advances in science and technology usually bring social benefits.

Personal Value of Science

The personal value of science is whether science is important in a student´s own life and affected their behaviour. The personal value of science relates to students´ value of science and the scientific advancement of understanding the world for their own sake, and the usefulness of science and scientific inquiry at an individual level. Personal value of science can be understood by answering the following:

- ❖ Some concepts in science help me see how I relate to other people.
- ❖ I will use science in many ways when I am an adult.
- ❖ Science is very relevant to me.
- ❖ I find that science helps me to understand the things around me.
- ❖ When I leave school there will be many opportunities for me to use science.

Students' Beliefs and Learning Science

Students' self-efficacy and self-concept have the strongest positive associations with scientific literacy.

Self-efficacy in Science

To understand how confident the students are, they can be asked to:

- ❖ Recognise the science question that underlies a newspaper report on a health issue.
- ❖ Explain why earthquakes occur more frequently in some areas than in others.
- ❖ Describe the role of antibiotics in the treatment of disease.
- ❖ Identify the science question associated with the disposal of garbage.
- ❖ Predict how changes to an environment will affect the survival of certain species.
- ❖ Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars.
- ❖ Interpret the scientific information provided on the labelling of food items.
- ❖ Identify the better of two explanations for the formation of acid rain.

Self-concept in Science

The following statements will help the teachers understand self-concept of students:
- ❖ Learning advanced science topics would be easy for me.
- ❖ I can usually give good answers to test questions on science topics.
- ❖ I learn science topics quickly.
- ❖ Science topics are easy for me.
- ❖ When I am being taught science, I can understand the concepts very well.
- ❖ I can easily understand new ideas in science.

Interest, Engagement and Motivation in Science

Learning becomes joyful when students have interest, motivation and engagement in the subject.

General Interest in Science

To measure how interested students are in science, the following topics are helpful:
- ❖ physics,
- ❖ chemistry,
- ❖ astronomy,
- ❖ geology,
- ❖ biology of plants,
- ❖ human biology,
- ❖ ways scientists design experiments, and
- ❖ what is required for scientific explanations.

Enjoyment of Science

The following topics can make students think about their attitudes to science and learning science:
- ❖ I generally have fun when I am learning science topics.
- ❖ I like reading about science.
- ❖ I am happy doing science problems.
- ❖ I enjoy acquiring new knowledge in science.
- ❖ I am interested in learning about science.

Instrumental Motivation in Science

The following five statements put to students will help them assess the teacher how instrumentally motivated students are:
- ❖ Making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on.

- ❖ What I learn in my science subject(s) is important for me because I need this for what I want to study later on.
- ❖ I study science because I know it is useful for me.
- ❖ Studying my science subject(s) is worthwhile for me because what I learn will improve my career prospects.
- ❖ I will learn many things in my science subject(s) that will help me get a job.

Responsibility towards Resources and Environments

Scientific literacy equips students to assess environmental situations, to demonstrate a willingness to take action to maintain natural resources, and to show a sense of personal responsibility for maintaining a sustainable environment.

Responsibility for Sustainable Development

Teachers can assess how responsible their students are towards sustainable development by asking them how much they agree with the following statements:
- ❖ It is important to carry out regular checks on the emissions from cars as a condition of their use.
- ❖ It disturbs me when energy is wasted through the unnecessary use of electrical appliances.
- ❖ I am in favour of having laws that regulate factory emissions even if this would increase the price of products.
- ❖ To reduce waste, the use of plastic packaging should be kept to a minimum.
- ❖ Industries should be required to prove that they safely dispose of dangerous waste materials.
- ❖ I am in favour of having laws that protect the habitats of endangered species.
- ❖ Electricity should be produced from renewable sources as much as possible, even if this increases the cost.

Awareness of Environmental issues

Students can be asked to give their views on the following issues and this will be useful in assessing the awareness of students towards environmental issues:
- ❖ The increase of greenhouse gases in the atmosphere.
- ❖ Use of genetically modified organisms (GMO).
- ❖ Acid rain.
- ❖ Nuclear waste.
- ❖ The consequences of clearing forests for other land use.

Concern for Environmental Issues

Students can be asked whether the following are serious concerns for them:

❖ Air pollution.
❖ Energy shortages.
❖ Extinction of plants and animals.
❖ Clearing of forests for other land use.
❖ Water shortages.
❖ Nuclear waste.

3.2. Paradigm Shift in Teaching-Learning of Science

Science is taught as a compulsory subject in schools till class X. It is a part of Environmental Studies in the primary classes (classes III to V) and as an independent subject in the upper primary and secondary classes (Classes VI to X). After class X, the students may choose any of the available streams. The national boards like the Central Board of Secondary Education (CBSE) and the National Council of Educational Research and training (NCERT) decide the curriculum and assessment strategies for the schools affiliated to the Board. Though the curriculum is uniform across the country, there are also non-uniformities due to various causes like socio-economic difference between rural and urban India. In most of the under-privileged strata of the society, teaching of science is limited to reading of textbooks and answering the questions given at the end of the lessons. Most of the students have weak understanding of the concepts and they find it difficult to relate science to their daily lives. Presently, the focus is on exam-centered approach that helps the students score more in the term-end exams and with no relation to application of scientific knowledge in real life. This unproductive methodology has resulted in a generation that lacks skill and is unemployable. To overcome this situation, a paradigm shift is required in teaching of science.

New Paradigm of Science teaching

Using Multiple Intelligences in Science Teaching- The focus of teaching is to arouse students' curiosity and motivation to think, act, investigate, explore, and learn. Also, science teaching is to share with students the joy of process and outcomes of science learning. To teachers themselves, science teaching is a life-long learning process involving continuous discovery, experimenting, self-actualization, reflection, and professional development particularly in the area of science. Science teachers should develop using multiple intelligences of students in order to maximise teaching-learning of science.
According to Howard Gardener, there are following eight types of multiple intelligences (MI):

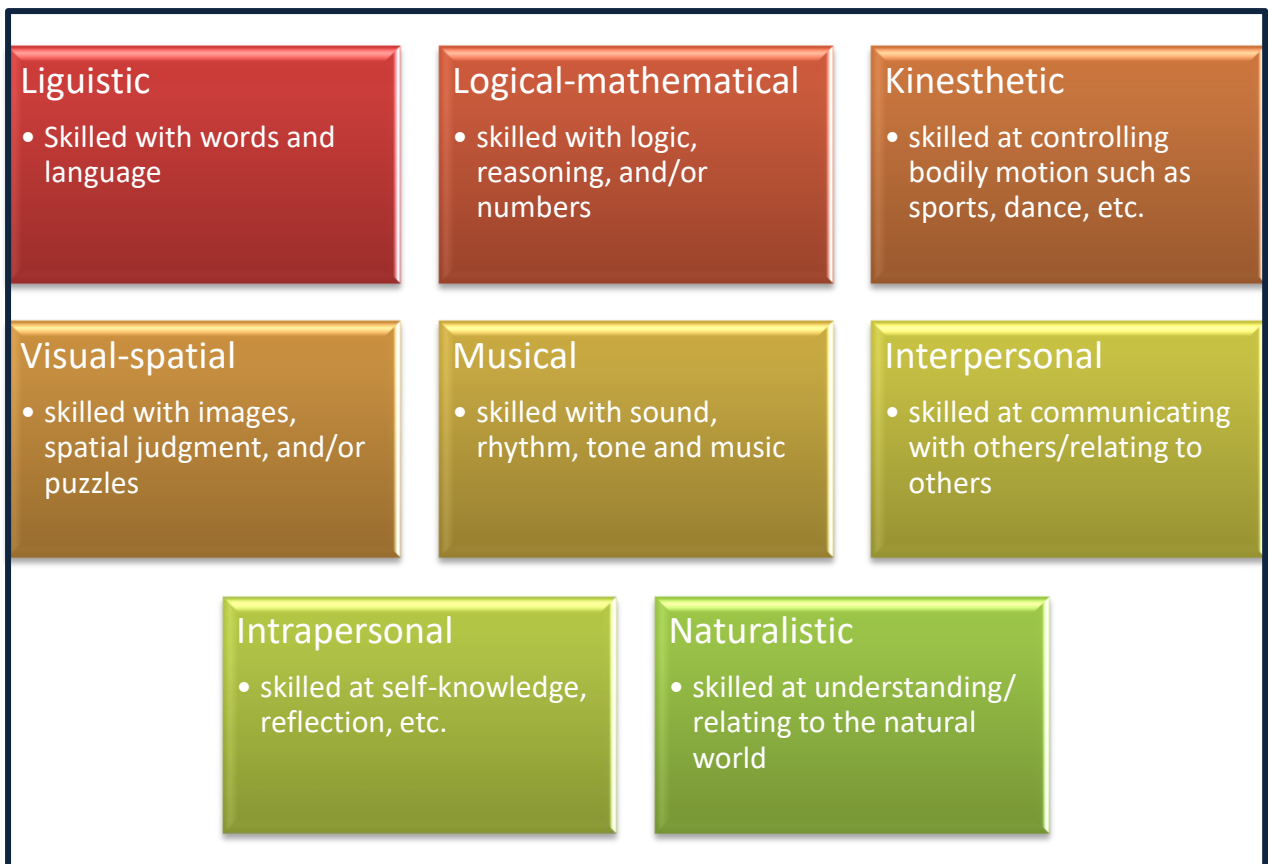| Liguistic	Logical-mathematical	Kinesthetic
• Skilled with words and language	• skilled with logic, reasoning, and/or numbers	• skilled at controlling bodily motion such as sports, dance, etc.
Visual-spatial	**Musical**	**Interpersonal**
• skilled with images, spatial judgment, and/or puzzles	• skilled with sound, rhythm, tone and music	• skilled at communicating with others/relating to others
Intrapersonal	**Naturalistic**	
• skilled at self-knowledge, reflection, etc.	• skilled at understanding/ relating to the natural world	

Figure 3: Eight types of multiple intelligences

The knowledge of MI helps teacher know his/her students better. Making assignments to reach all the MI can be very time consuming. So, teachers can pick one or two intelligences that they normally do not use in their lessons and find a way to incorporate them.

Localised and Globalised Science Teaching- The new paradigm emphasises that teachers in their teaching should be facilitated in such a way that all science teaching activities can bring in local and global resources, supports and networks to maximize the opportunities for their developments in science teaching and their contributions to students' science learning. Through localization and globalization, there are multiple sources of science teaching other than the textbooks; for example, science laboratories, self-learning programmes, experiential programs- inside and outside their schools, locally and globally. Teachers can maximize the opportunities to enhance effectiveness of their science teaching from local and global networking and exposure through Internet, web-based teaching, video-conferencing, cross-cultural sharing, and different types of interactive and multi-media materials.

Science teaching is not limited to reproduction and perpetuation of the existing science knowledge, but to make the student use the knowledge in real life.

Traditional Paradigm of Science Teaching	New Paradigm of Science Teaching
Reproduced Science teaching: • Science teacher and textbook is the centre of science education. • Standard teaching styles and patterns to ensure standard science knowledge • The major task is to transfer some knowledge and skills of science to students. • Science teaching is a disciplinary, delivery, training and socialising process. • Science teaching is hard work to achieve some external standards in science examinations. • Science teacher is a practice of application, or transfer of the previous science knowledge the teacher already owns.	**Using Multiple Intelligences in Science teaching:** • Science teacher is the facilitator or mentor to support students' science learning. • Different teaching styles to cater multiple intelligences of students • The focus of science teaching is to arouse students' curiosity and motivation to think, act, investigate, explore and learn. • Science teaching is a process to initiate, facilitate, and sustain students' self-learning and self actualisation. • Science teaching is to share the joy of process and outcomes of science learning with students. • Science teaching is a life-long learning process involving continuous discovery, experimenting, self-actualisation, reflection and professional development.
School-bound Science Teaching: • Schools are major venue for science teaching and teachers and textbooks are the major source of science knowledge. • Science teaching limited to science department • Science teachers and their teaching are alienated from the fast changing local and global communities.	**Localised and Globalised Science Teaching:** • There are multiple sources of science teaching inside and outside their schools, locally and globally. • Inter-disciplinary science teaching • Participation in local and international development programmes to achieve the related outlook and experiences in science and science education beyond schools

Figure 4: Comparison between traditional and new paradigms in science teaching

3.3. What Can Science Teachers do?

No science teacher can play an effective role in developing a scientific attitude among the students if the teacher fails to adopt it him/herself. Students tend emulate their teachers and hold them in high esteem.

Teachers, hence, can provide a number of opportunities to their students by adopting some of the following measures:

- Increasing the degree of consistency and exposure of the scientific environment in which the students get education
- Giving stimulus to students to make them think scientifically
- Children are curious by nature and a teacher can make arrangements in a classroom/ school to satisfy their curiosity.
- A number of encouraging questions should be asked and the teacher should try to provide satisfactory answers.
- Opportunities for close observation should be provided by way of hands-on experience and experimentation.
- The task of collecting evidence by way of survey method can also be inculcated.
- The spirit of self-exploration and investigation should be encouraged.
- Students will learn to make effective use of their previous knowledge if they are led from the unknown to the known.
- A complete freedom in their thoughts should be provided to the students. Teachers can play an effective role in this by not providing them with ready-made responses.

Science is a practical subject for which the given suggestive teaching methods will go a long way in providing, finding, and exploring scientific aspects of relevant fields of knowledge:

> ❖ **Design based learning (DBL)**- Also known as design-based instruction, it is an inquiry based form of learning, or pedagogy, that is based on integration of design thinking and design process into the classroom at secondary levels. DBL, as well as project-based learning and problem-based learning, is used to teach the 21st century skills such as communication and collaboration and foster deep thinking.

> ❖ **Project based learning (PBL)**- It is a student-centered pedagogy that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge through active exploration of real world challenges and problems. Students learn about a subject by

working for an extended period of time to investigate and respond to a complex question.
❖ **KWL table-** **KWL** is an acronym for what students already **k**now, **w**ant to know and ultimately **l**earn. It is a part of constructivist teaching method where students move away from traditional teaching-learning. The KWL chart is has three columns titled KNOW, WANT and LEARNED. It is useful for research projects.
❖ **5E's Learning Cycle-** It is an instructional design model that defines a learning sequence based on the experiential learning philosophy. It says that learners build or construct new ideas on top of their ideas. Each of the 5 E's describes a phase of learning. These phases are- Engage Explore, Explain, Elaborate, and Evaluate. The 5 E's allows students and teachers to experience common activities, to use and build on prior knowledge and experience, to construct meaning, and to continually assess their understanding of a concept.
❖ **Experiential Learning-** It is the process of learning through experience, and is more specifically defined as 'learning through reflection on doing'. Experiential learning enables skills to be learnt and practised in classroom and then practically applied in real life situations.
❖ **Peer-based learning-** Peer based learning or peer learning is an educational practice in which students interact with other students to attain educational goals. It can take place in both- formal and informal contexts.
❖ **Educational tours-** Educational tours let students know more and dig deep into many concepts and explore them.
❖ **Science exhibitions-** Science exhibitions give opportunity to students to present their science project in form of report, display board, and/or models that they have created. Responsibility of arranging a Science Fair/ Exhibition should be laid on the shoulders of students.
❖ **Science conferences/ symposiums-** Science seminars and conferences are platforms where experts and teachers from other institutions are invited must be organised.
❖ **Science experiments-** Science experiments promote discovery and learning. Experiments allow trial and error and students learn from their mistakes and understand potential gaps between theory and practice.

Effective use of laboratory period can help students utilise their time fruitfully in attaining conceptual knowledge. Simple experiments can be conducted in the morning assembly to ignite curiosity and interest in students.

❖ **Multi-disciplinary projects**- The term 'multi-disciplinary' refers to an approach which creates a single team from a range of different disciplines or fields of expertise. A multi-disciplinary approach can tackle complex situations or problems by using the combined skills of different disciplines to develop holistic solutions.

3.4. Government's Initiatives to Enhance Scientific Literacy

i. **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 would teach students pan-India the essential 21st century skills which will help them develop their professional and personal skills. Young children will get a chance to work with tolls and equipments to understand what, how, and why aspects of STEM (Science, technology, engineering, and mathematics). ATL would contain educational and learn 'Do it yourself' kits and equipments on electronics, robotics, open source micro-controller boards, science, sensors, and 3-D printers.

Figure 5- Atal Tinkering Labs in Schools

ii. **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 more particularly their ability to solve a societal problem experienced locally using by method of science.

Figure 6- Exhibits of NCSC

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

Figure 7- Students demonstrating their exhibits in Jawaharlal Nehru National Science Exhibition

iv. **Kishore Vigyan 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 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.

Selection of the students is made from those studying in XI standard to 1st year of any undergraduate Program in Basic Sciences.

v. **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 includes medals, trophies and plaques, as well as scholarships.

Talent tests – at a Glance
(from school level to Intermediate)

S.No	Name of the Exam	Eligible Students	Syllabus	website
1	NTSE (National Talent Search Exam)	10 th class students	Science, Maths , Social , Mental ablility	www.ncert.nic.in
2	KYPY (Kishor Vygnanika Proshaah Yogena)	Inter (MPC /BiPC)	Inter syllabus	www.kypy.iisc.ernet.in
3	HBBVS (Dr. Homi Baba bala vidyanic spertha)	6 to 9 th class students	CBSE/ICSE Syllabus	www.instrs.in
4	NSO (National Science Olympiad)	1 to 12 th class students	CBSE/ICSE Syllabus	www.sofworld.org
5	NCO (National Cyber Olympiad)	1 to 12 th class students	CBSE/ICSE Syllabus	www.sofworld.org
6	UCO (Unified Cyber Olympiad)	8 to 12 th class students	Mental ability, Reasoning, Computer Skills	www.unifiedcouncil.com
7	NTSE (National Science Talent search Exam)	1 to 12 th class students	CBSE/ICSE Syllabus	www.unifiedcouncil.com
8	MTSE (Maths Talent Search Exam)	3to 9 th class students	Mental ability, Reasoning, Maths	www.ganithasastraparishad.org
9	IMO (International Mathematics Olympiad)	1 to 12 th class students	CBSE/ICSE Syllabus	www.imo_official.in
10	NLSTSE (National Level Science Talent Search Exam)	1 to 12 th class students	CBSE/ICSE Syllabus	www.unifiedcouncil.com
11	NSEJS (National Standard Exam in Junior I Science)	1 to 10 th class students	CBSE/ICSE Syllabus	www.iapt.org.in
12	SSTSE (State Level Science Talent Search Exam)	4 to 10 th class students	SCERT Syllabus	www.unifiedcouncil.com
13	IAIS (International Assessment for Indian Schools)	3 to 12 th class students	CBSE/ICSE / SCERT Syllabus	www.macmillaneducation.in/iais
14	IOS (International Olympiad in Science)	1 to 12 th class students	CBSE/ICSE Syllabus	www.sofworld.org
15	RMO (Regional Mathematics Olympiad)	Intermediate	CBSE Syllabus	www.isical.ac.in
16	IOEL (International Olympiad of English Language)	1 to 12 th class students	CBSE/ICSE Syllabus	http://schools.aglasari.com
17	NSIB (National Standard Exam in Biology)	Senior Inter Students	CBSE Syllabus	http://iapt.org.in
18	NSEC (National Standard Exam in Chemistry)	Senior Inter Students	CBSE Syllabus	http://iapt.org.in
19	NSEA (National Standard Exam in Astronomy)	Senior Inter Students	CBSE Syllabus	http://iapt.org.in
20	NSEP (National Standard Exam in Physics)	Senior Inter Students	CBSE Syllabus	http://iapt.org.in
21	ZIO (Zonal Information Olympiad)	8 to 12 th class students	CBSE Syllabus	www.iarcs.org.in
22	IIO (International Information Olympiad)	1 to 8 th class students	CBSE/ICSE / SCERT Syllabus	www.iarcs.org.in
23	NIMO (National Interactive Mathematics Olympiad)	5 to 12th class students	Maths, Science, Mental Ability	www.eduhealfoundation.org
24	NBTO (National Bio-Technology Olympiad)	5 to 12th class students	CBSE/ICSE / SCERT Syllabus	www.eduhealfoundation.org
25	IGO (Indian Geography Olympiad)	2 nd to 12th class students	CBSE Syllabus	www.geogeniusindia.com
26	KO (Knowledge Olimpiade)	2 nd to 12th class students	CBSE/ICSE / SCERT Syllabus	http://aisect.org

3.5. Approach to PISA 2021

There are number of tasks and activities that can be used to develop scientific attitude and to prepare students for PISA like assessments. The activities given in the NCERT textbooks are a good source to enhance critical thinking. In addition to them, teachers can design a number of activities/ tasks that will help the students.

A few suggestive activities that the science teachers can adopt in their classroom teaching are given below:

1. **Fun with Words**- Word games are a good method of enhancing scientific vocabulary. Crosswords, word-search, spider web of words, picture glossary, prefixes and suffixes of science terminology, are some of the word games that can be done in classrooms.

   For example, photosynthesis can be broken down into smaller words and taught as: **photo** = light, **synth** = make and **isis** = process. That way, your students will be more likely to remember that photosynthesis has *something* to do with light and the process of making something.

2. **Puzzles and Riddles**- Puzzles and riddles have secret meaning mission and the students find it fun to crack them. Teachers can ask the students to prepare their own riddles and puzzles and they will come out with amazing brain-teasers. Sudoku and Kakuro puzzles provide an excellent source to learn organizing thoughts and ideas.

3. **The Gift of Gab**- Oratory activities not only help the students communicate better, they also help in organising their thoughts and ideas, think critically, and respond promptly. Debates, group discussion, JAM (just a minute) are a few activities that can enhance the oratory skills.

4. **Surveys and Reporting**- Conducting a survey and preparing its report not only link knowledge to life, but also enhance observation and classification skills. The students learn collection of authentic data and prioritisation. They can be asked to conduct surveys on various issues within the school campus.

5. **Data Interpretation**- Surveys provide the students with a lot of data and they can make use of it only when they learn to interpret it. Data interpretation deals with graphical interpretation, abstraction, and data handling.

6. **Reading Skills**- Reading skill is the backbone of all learning. It is not only the English teachers who should focus on reading skills. In science, if the student is not

able to read and comprehend the given text, s/he won't be able to apply her/his acquired knowledge. Various kinds of reading passages related to scientific issues can be given to test their application of knowledge.

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References-
1. PISA FOR DEVELOPMENT ASSESSMENT AND ANALYTICAL FRAMEWORK: READING, MATHEMATICS AND SCIENCE © OECD 2018
2. A teacher's guide to PISA scientific literacy by ACER Press, Victoria, Australia

CHAPTER 4-SAMPLE SCIENTIFIC LITERACY ITEMS

4.1. Bubbles

'Bubbles' we all know how fascinating they are. A bubble's fragile nature, beautiful rainbow colours and ability to soar through the sky makes them fascinating. A bubble is just air wrapped in a soap film. Soap film is made from soap and water. It is very difficult to blow bubbles from plain water; it is because every liquid surface tends to minimize its surface area. Even soap added water has this tendency but at a highly reduced level. This tendency minimizing surface area is termed as surface tension. Adding soap solution or adding kerosene oil reduces the surface tension of water.

A soap bubble gets busted after a while because the water gradually gets evaporated and the walls of the bubble become gradually thinner, here is a graph showing the variation of thickness of the walls the bubble vs. time.
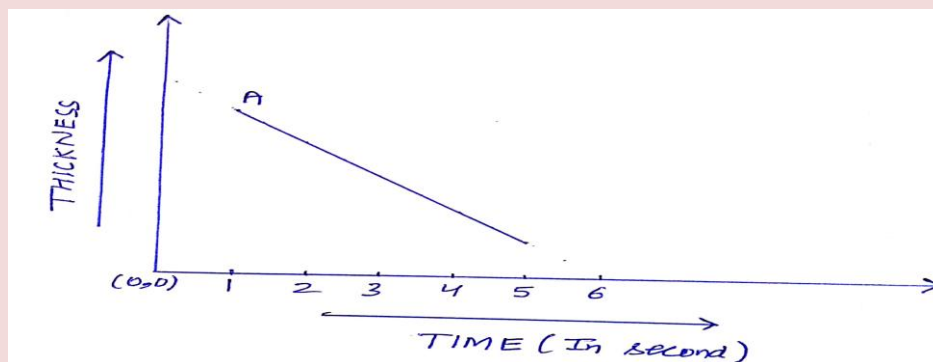
We have seen that a plastic ball rises in water because a lighter object rises in a heavier fluid, similarly a soap bubble may rise in air if it is lighter than the surrounding air. If the air blown in the bubble is lighter than the surrounding air then the bubble rises in air and keeps rising unless it gets evaporated.

BUBBLES- Question 1

The first question of 'Bubbles', is a multiple choice question, which assesses application of existing knowledge to explain a phenomenon. Students are asked to identify the reason behind formation of bubbles in soap water. Students need to rely on their skill to apply their scientific knowledge to a common day-to-day occurrence. The question is set in daily life context. This item is an example of an easy scientific literacy item, with a multiple-choice format.

Question1)-According to the above given text, Why do we add soap to water?
a) To reduce the tendency of water to minimize its surface area
b) To increase the tendency of water to minimize its surface area
c) To increase the temperature of water
d) To make water heavier

Competency	To retrieve information
Knowledge-system	Content knowledge
Context	LOCAL
Cognitive demand	Medium
Item format	Simple MCQ

BUBBLES- Question 2

This question assesses the competency 'explaining phenomena scientifically'. Students are asked to compare the surroundings of two bubbles. To answer this question, students must have knowledge of physical systems, particularly the relationship between pressure and temperature. Students have to demonstrate the ability to understand scientific theories and the purpose of using atmospheric variables. To score full credit in this question, the student has to explain the relationship between surface tension and atmospheric conditions.

Question 2)- If two identical bubbles are formed, one each in two different surroundings, with one surrounding having a higher temperature and other having a lower temperature. Which bubble will be the first to burst? Discuss the possible cause.

…………………………….

Competency	Explaining phenomena scientifically
Knowledge-system	Content based
Context	local
Cognitive demand	High
Question format	Constructed response

BUBBLES Question 3

This question is an open constructed response item that focuses on explaining phenomenon scientifically and thus assessing the 'using scientific evidence' competency. It also assesses students' knowledge about scientific explanation. For answering this question, student must

be able to conclude that various physical phenomenon like bubbles, ultrasound, and magnetic waves can be used in a combined way to discover methods of treatment.

In a study at Oxford University, researchers have focussed on making stable micro bubbles, which can contain chemotherapeutic drugs (used to treat cancer).With traditional chemotherapy typically only 0.001-0.01%of the injected does reach the tumour. The remaining drug leads to severe side effects. The researchers are working to design stable micro bubbles which, combined with ultrasound, can deliver cancer drugs straight to the target tumour. The aim of the work is to make long -circulating drug loaded bubbles to be used in cancer treatment.

In their experimentation they found that the bubbles with the drugs are attracted towards the magnetic field. The size of this micro bubbles is same (OR less than) as the red blood cell and they are stable enough to carry blood with them. From the past study, it's also known that the bubbles respond to ultrasound and can collapse as an effect.

Question3) A-Can you suggest possible effective cancer treatment method using their study?

………………..

Competency	Interlink of Science & Technology
Knowledge system	procedural
context	global
Cognitive demand	Medium
Question format	Open constructional approach

4.2. Meteorites and Meteors

A bright flash of light. Moments pass. Then, a rumble. The ground shakes a little. It can be only one thing — thunder and lightning. Right? That's what most residents of Eastern Michigan thought when they heard a boom just after 8 p.m. on January 16.The only problem? It was below freezing and there was hardly a cloud in the sky. That's not the expected environment for a thunderstorm. The most likely culprit was a meteor.

The reason people could witness the meteor's flight was the incredible amount of light the rock produced as it raced through the atmosphere at 11.26 kilometres (7 miles) a second.

Most meteors, including this one, are chondrites. They are made of tiny chondrules, mineral bits containing silicon. Meteors also have a lot of iron, nickel and magnesium. The latter is the reason they appear to glow blue. Magnesium burns white, but only the blue rays penetrate to the ground.

METEORITES AND METEORS Question 1

This question is a multiple choice question, which asks students to calculate the time the meteorite will take to hit the earth. For answering this question, students need to have previous knowledge of relationship between time and distance. Students must also think about factors like gravity and acceleration.

Q1: How long will it take for the meteorite to strike the surface of the earth? Assume that it doesn't get burnt up before hitting the earth's surface and the height of atmosphere is 500km.

………

………

………

Situation: Personal
Aspect: mathematical analysis
Question format: Close constructed response
Cognitive demand: medium

METEORITES AND METEORS Question 2

This is a binary choice question which assesses analysing skill of students. Students have to use the information given in the passage and critically examine each item below and come to a conclusion. This question assesses 'expanding phenomenon scientifically' competency.

Q2

Can the following be a hurdle to watch meteor shower?	Yes/No
A bright moon light	Yes/No
Cloudy sky	Yes/No
Pollution in the air	Yes/No
A Pitch Dark sky	Yes/No

Situation: Personal
Aspect: Thinking
Question format: Multiple choice
Cognitive demand: High

4.3. Heat

The most common hazard in forests is forests fire. Forests fires are as old as the forests themselves. According to Down To Earth current report, forest fires in India increased by 125 per cent in last two years. Madhya Pradesh recorded most forest fires than any other state in 2017. At the end of 2017, the maximum number of forest fires were reported in Madhya Pradesh (4,781) followed by Odessa (4,416) and Chhattisgarh (4,373). During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twinges, which would burst into flames ignited by the slightest spark. Forest fires are caused by natural causes as well as man-made causes. Natural causes include lightning which set trees on fire. High atmospheric temperatures and dryness (low humidity) offer favourable circumstance for a fire to start. Fire is caused when a source of fire like naked flame, cigarette or *bidi*, electric spark or any source of ignition comes into contact with inflammable material. All these are human initiated causes of forest fires. These fires are a major cause of forest degradation and have wide ranging adverse ecological, economic and social impacts. A group of school students along with their facilitator has been scheduled to visit a forest in Madhya Pradesh for a week in May. While crossing the check post, the school children were not allowed to carry few things with them.

HEAT Question 1

The first question in the unit 'Heat' asks the students to explain the reason why some items catch fire easily. They have to use the information given in the question and apply it to explain whether steel utensils are flammable. This item is framed in personal settings of day-to-day life of students. They are required to demonstrate their critical thinking to analyse the reason behind stee lwool being combustible and steel utensils being non-combustible.

Question 1.

A group of things were categorized as flammable and non flammable by the security reasons.

Flammable	Non flammable
1. Papers carried to note down the information about flora and fauna observed in the forest	1.Compass to find directions
2.Steel wool	2.Steel utensils

The students were really surprised that they were not allowed to carry steel wool. They were told that they may catch fire. Their teacher explained them that to produce a fire, a material should self-sustain its burning. The strands of steel wool are thin enough with enough surface area that heat produced is self sustaining and will continue to burn through if there is enough air present.

What do you think as a reason that steel utensils are non flammable? Explain.

Knowledge System – Procedural
Competency - Evaluate and design scientific enquiry
Content- Physical System
Context –Global
Cognitive Demand – Medium

HEAT Question 2

This cognitive question assesses the competency 'identifying scientific phenomenon'. To answer this question, students must have knowledge of climatic systems. The context of this question relates to solutions to forest fires and it is framed in social settings. Students have to demonstrate an ability to relate various realms of science.

Question 2

The Aravalli Mountain range is one of the oldest in the world. Its forest extends across more than 693 kilometres from Champaner in Gujarat all the way to Delhi, through Rajasthan and Haryana. The government is planning to increase the groundwater table of the forest region. One of the expected advantage of such an initiative is reduction in number of forest fire incidents in forest.

Do you think that increase in groundwater table can really help to reduce forest fires? Justify your answer.

Knowledge System – Procedural
Competency - Evaluate and design scientific enquiry
Content- Physical System
Context –Global
Cognitive Demand – Medium

4.4. Rabies

Representative from 11 countries recently convened at WHO headquarters to devise plans to end human rabies death by 2030. People are now using mobile technology to access facilities that provide free anti-rabies vaccination to dogs. Symptoms of rabies can take weeks or months to start showing. This can include general weakness, discomfort, prickling, itching sensation around the bite and the last stage is delirium, abnormal behavior and hallucinations.

Rabies is most common in countries where stray dogs are present in large numbers, especially in Asia and Africa. It is passed on through saliva. The closer the bite is to the brain, the sooner the effects are likely to appear. Rabies progresses in five distinct stages: incubation, prodrome, acute neurological period, coma and death. (**161 words**)

RABIES Question 1

This question is binary choice which assesses the ability to draw evidence-based conclusions about science related issues. Students are asked whether the claims made in the article help explain the statements given in the question. It also helps students evaluate scientific enquiry through critical analysis.

Question 1: People generally seek immediate medical attention after a suspected dog bite as they fear being infected with rabies. Few people understand that it is a preventable and curable disease. In this context, circle '**Agree'** or '**Disagree'** for each of the followings facts:

a) Rabies is spread by the teeth of a dog   .   Agree/disagree

b) Symptoms of rabies are visible within two days in humans.
                                                Agree/disagree

c) Humans may survive rabies without vaccination or treatment.
                                                Agree/disagree

d) Rabies is fatal if symptoms are visible   Agree/disagree

Situation	Global
Aspects	Evaluate scientific enquiry
Question type	Binary choice question

RABIES Question 2

This is a cognition based question that assesses the competency 'identifying scientific issues'. In this question students are expected to relate the knowledge of climatic conditions in Antarctica with rabies. This will also assess whether students have understood the characteristic features of science as a form of human knowledge and enquiry.

Rabies- Question 2

Rabies is an infectious disease and it is present in all continents of the world except Antarctica. Why do you think rabies is not prevalent in the continent of Antarctica?

Situation	Global
Aspects	Explain phenomenon scientifically
Question type	Open constructed response

CHAPTER 5- ASSESSMENT AS A TOOL OF LEARNING, WHY AND HOW

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 teaching-learning processes. It assesses teacher effectiveness and learning outcomes both.

5.1. Assessment- Why?

At the end of every lesson, the teacher is curious 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?**

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 the indicator like 'teamwork'?
• Whether learning outcome has been achieved

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

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

- ✓ **What is important to learn**
- ✓ **What have I learnt**
- ✓ **What I have not learnt**
- ✓ **Where to improve**
- ✓ **How to improve**

According to 'Source Book on Assessment' by NCERT, in science subject, assessment should focus on whether the child has learnt 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 that has taken place. Such 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 learner's abilities as various methods are used to collect data about learner's achievement and their work is analysed, feedback is given so that the learner can take responsibility of his/her learning.

5.2. Assessment- How?

Assessment is integral to the teaching-learning process, facilitating student learning and 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).
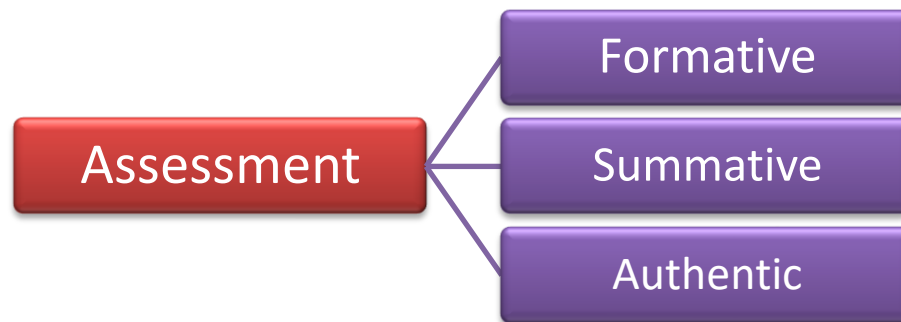
Assessment *for* Learning (Formative Assessment) - Assessment *for* learning is ongoing assessment that allows teachers to monitor students on a day-to-day basis and modify their teaching based on what the students need to be successful. This assessment provides students with the timely, specific feedback 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.

Assessment *as* Learning (Authentic Assessment) - This form of assessment is crucial in helping students become a life-long learners. This assessment can also be called as 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.

5.3. Why Authentic Assessment?

So far, formative and summative assessments are used by our teachers that test what the students have learnt in school. But, the purpose of education is the 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.

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 vs. Authentic Assessment

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

Following are some tasks that can be used for authentic assessment-

a) **Performance of Tasks**- When students perform tasks before some audience like teachers, peers, community members, and/or experts to show what they know and what they are able to do, it is authentic assessment of what they have learnt.
This audience evaluates the quality of performance with 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**- As the name implies, extended tasks are assignments that require sustained attention and last longer than 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- at 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.

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 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.

5.4. Assessment using Rubrics

A rubric 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". Rubrics can be designed for any content domain. Rubrics 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 highest and 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
Scientific Concepts	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.
Procedures	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.
Drawings/Diagrams	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.
Analysis	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.
Handling of Materials/ Equipment	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.
Practical Notebook	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.

5.5. Strategies for Learning from Assessment

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

a) **Reflection by the students-** Reflection is about students becoming aware of their own thinking processes, and being able to make those transparent to others. It enables assessment of the "why" and "how" of the 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 learnt
   ii) where they have got to
   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 learnt. 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.

References:
- Source Book on Assessment, NCERT
- Official website of University of New South Wales, Sydney (https://www.unsw.edu.au/)
- Curriculum for PLI, OEF
- http://rubistar.4teachers.org

5.6. Conclusion

India's participation in PISA 2021, for the second time in the history of the nation, will measure to a large extent, the key competencies, its 15-year old students have acquired: skills that are paramount for their participation as global citizens in a fast paced modern world. The country's performance at the PISA-2009, the first time India had participated in a modern international assessment was dismal. The performance of the students highlighted the pressing need of bringing in educational reforms and an urgent need to revamp the efforts on the part of its stakeholders to help students score better in future.

A small group of selected students of KVS, NVS, and the UT of Chandigarh will take the PISA 2021. In the words of the Honourable HRD minister, Shri Prakash Javdekar, ''We will move from national assessment to international assessment.'' He added that the outcomes of the assessment will help introduce curricular reforms, and improve teacher-training programmes. The educational and evaluative amelioration will help focus on competency based teaching, remove rote learning from the system, and set new bench marks for the educational institutions.

India looks forward for preparing its students for PISA 2021. A paradigm shift towards skill based teaching is expected in the Indian classrooms. The teachers' guide, in this sense, will play the crucial role of acquainting the educators with PISA standard material, the expected learning outcomes and the strategies requisite for achieving these pedagogical objectives.

The scope of educational reform is massive: educationists opine that these reforms are long overdue in our country. Many jobs in future rely heavily on candidates with a solid foundation in Science and Technology, besides complimenting the Social Sciences. The PISA 2021 assessment in that sense will ensure curricular refinement, enhance teacher quality and attain the desired learning outcomes.