A COMPETENCY-BASED LEARNING FRAMEWORK FOR SCHOOL SCIENCE

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Many education policies recommend science curricula that help students develop competencies like scientific temper and skills, and not merely learn facts. How can teachers connect these competency-based outcomes with the curriculum, as well as with their pedagogical and assessment practices?

In the past few years, there has been a thrust towards a competency-based approach to education across all educational policy documents (see **Box 1**). For example, the National Educational Policy (NEP) 2020 strongly recommends that the science curriculum adopt an interdisciplinary, competency-based approach that helps develop sensitivity, evidence-based thinking, scientific temper, and innovativeness in students (see **Box 2**).

However, schools face many challenges in implementing this approach in the teaching and learning of science. Important systemic challenges include a shortage of secondary-level teachers with training in science, a lack of physical infrastructure such as labs, etc., and inadequate teacher support. At the classroom level, pedagogical processes and assessment practices at all grades tend to reinforce the memorization of scientific facts over mastery of scientific skills. This is partly due to what is commonly understood as being the goals of science education, and partly because of the nature of board examinations. For example, a study conducted by Azim Premji University showed that an average of 60-70% of the questions in the Grade X science examination papers of selected Boards of India tested recall of facts and information. Also, close to 40-50% of questions in the paper were directly lifted from the prescribed textbooks. In contrast, almost all the process skills of science, such as hypothesizing, drawing inferences, predicting, analysing, etc., were left untested. Several secondary

Box 1. What is competency-based teaching and learning?

Competency-based education aims to ensure that learners demonstrate the attainment of expected learning outcomes for the school curriculum. It requires learners to be involved as active participants in teaching-learning processes in the classroom; and also emphasizes the need for them to be capable of applying the desired knowledge, attitudes, and skills in diverse contexts.

Box 2. What is the NEP 2020?

It is a comprehensive framework of recommendations for guiding the development of our country's education system. These recommendations cover many aspects of education—including the structure of schooling, curriculum, pedagogy, assessment, teacher training, school administration, and its governance.

school science teachers have shared how such examination papers contribute in significant ways to a narrowing of the science syllabus that gets transacted at the secondary level.

In order to overcome these challenges, it is important to arrive at a common shared understanding of the goals and outcomes of science. It is from this perspective that the National Council of Educational Research and Training (NCERT) has identified and published Learning Outcomes (LOs) for Grades VI-X. However, several teachers find the LOs quite abstract and disconnected from their practice. This is mainly because these documents offer little clarity on the interlinkages between these LOs and the prescribed textbooks for these grades. Also, they lack adequate guidance on ways to translate these LOs into classroom practices through appropriable pedagogical and assessment strategies.

It is to address these gaps that the Central Board of Secondary Education (CBSE), with the support of Azim Premji University, has developed a science Learning Framework (LF). This framework helps practicing teachers see connections between the many different aspects of school science education—the curriculum (particularly its aims and objectives at various stages of schooling), NCERT's grade-appropriate LOs, pedagogical principles of teaching science, and the assessment of science learning in relevant and authentic ways (see **Fig. 1**).

Components of the LF

(a) Nature of subject: The LF outlines the various interconnected steps in the practice of science. These include making observations; looking for regularities and patterns; making hypotheses; devising qualitative or mathematical models; deducing the consequences of these models; verifying theories through observations and controlled experiments; and arriving at the principles, theories, and laws governing the physical world.

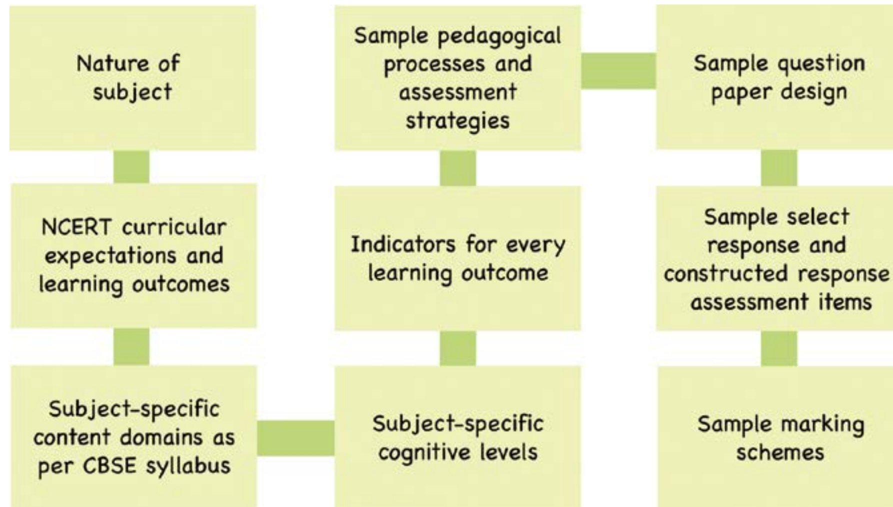


Fig. 1. Components of the Learning Framework.

(b) Learning Outcomes: The LF connects the LOs with the science-specific skills that students need to attain through different concepts addressed in their syllabus. For example, it recognises the fact that the focus of the secondary school curriculum shifts from familiarity with formal definitions to the comprehension of concepts, principles, and laws of science. Thus, it emphasizes the role of experimentation, often involving quantitative measurement, as a tool to discover or verify theoretical principles. In addition, it also stresses the need for students to be introduced to the skills of interpreting data and drawing inferences.

(c) Subject-specific content domains: To help teachers connect science-specific LOs with the CBSE syllabus and the prescribed textbook, the LF maps these outcomes to related content domains (like Food, Materials, The world of the living, How things work, Natural phenomenon, and Natural resources).

(d) Subject-specific cognitive levels: The LF expresses the LOs for science in terms of three subject-specific cognitive levels—knowing, applying, and reasoning (see **Box 3**). These levels describe the intellectual processes that students need to engage in to demonstrate the expected LOs (see **Fig. 2**).

Box 3. Cognitive dimensions in school science:

Knowing: This domain addresses the student's ability to recall, recognize, describe, and provide examples of facts, concepts, and procedures that are necessary for a sound foundation in science. Having accurate and broad-based factual knowledge enables students to successfully engage in the more complex cognitive activities essential to the practice of science.

Applying: This domain focuses on the student's ability to use knowledge to compare, contrast, and classify groups of objects or materials; relate knowledge of a science concept (facts, relationships, processes, concepts, equipment, and methods) to real-life contexts; generate explanations, and solve practical problems.

Reasoning: In contrast to the more direct application of facts and concepts in the previous dimension, LOs in the reasoning domain involve the application of facts in unfamiliar or more complex contexts. Thus, this domain focuses on the student's ability to engage in reasoning to analyze data, draw conclusions, and extend their understanding to new situations. Scientific reasoning also encompasses developing hypotheses and designing scientific investigations within and beyond classrooms.

Knowing

- Identifies the major cell structures such as nucleus, mitochondria, ER etc.
- Describes the differences between prokaryotic and eukaryotic cells.
- Provides examples of cell types that have chloroplasts.

Applying

- Compares plant and animal cells.
- Relates how guard cells help gas exchange in leaves.
- Uses a model to demonstrate how a cell is a dynamic entity.
- Interprets tabular, pictorial, and graphical information related to cells.
- Explains the 'how' of cellular respiration.

Reasoning

- Analyzes the structure and function correlation between intestinal villi and the rate of absorption.
- Responds to why calling cells as 'bricks' of our body doesn't justify what they actually are.
- Investigates, predicts, and verifies 'what if' scenarios for living cells under certain conditions.
- Justifies the complexity of animal and plant cells in contrast to bacterial cells.
- Designs an experiment on determining cell size.
- Investigates a sample of pond water to observe, draw, and record the variety of life forms in it.

Fig. 2. Examples of different cognitive dimensions from the chapter 'A living cell' in the Grade X NCERT textbook.

(e) Indicators for every Learning Outcome: For each LO, the LF also defines indicators aligned to the science-specific skills that students need to attain through different concepts addressed in the CBSE curriculum. This offers teachers a clear understanding of the scope of each LO, which can be immensely helpful in their ability to plan how to teach each chapter in a better way (see **Fig. 3**).

(f) Sample pedagogical and assessment strategies: The sample pedagogical processes and formative assessment strategies in the LF are designed to enable teachers to derive common principles that can help align their pedagogy and assessments with the LOs (see **Box 4**).

(g) Assessment items, sample questions, and marking schemes: The LF shares a sample set of assessment items that are designed to elicit two different kinds of responses from students—select responses and constructed responses. In select response type questions (see **Fig. 4**), the student is required to select the correct response from the many options provided; while in constructed response questions, the student is expected to produce the correct response (see **Fig. 5**). Each sample item is tagged with the corresponding textbook chapter, content domain, competency level, cognitive level, thinking process, difficulty level, marking scheme, and the average time required to respond to it. The LF recommends that the marking scheme be given as much importance as the assessment item. For example, in designing constructed response questions, particularly those assessing higher cognitive levels, it recommends that teachers allow scope for variations in student responses—fully correct, partially correct, as well as many levels of partially correct responses. Similarly,

Content domain, chapter & key concepts	Learning Outcome	Indicators
Materials; Chapter 1 – Matter in our surroundings Key concepts: Physical nature of matter; Characteristics of particles of matter; States of matter – solid, liquid, and gaseous; Changes in states of matter; Sublimation; Boiling; Evaporation – factors influencing the process.	Differentiates between the three states of matter - solid, liquid, and gas.	• Defines matter as solid, liquid, and gas using their characteristics. • Differentiates between the latent heat of vapourisation and the latent heat of fusion. • Differentiates between sublimation and evaporation. • Differentiates between the three states of matter based on shape, intermolecular spaces, and the continuous movement of particles. • Emphasizes the contrast between the three states of matter using specific examples. • Differentiates between plasma and Bose-Einstein Condensate.

Fig. 3. An example of Indicators for a Learning Outcome.

Box 4. Key principles involved in the design of sample pedagogical processes and assessment strategies in the LF:

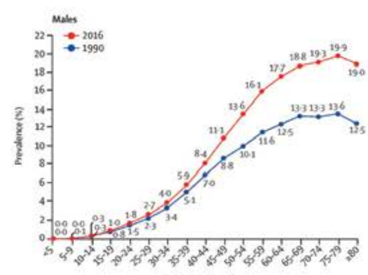
Student-centred: Since new knowledge is built over existing knowledge, pedagogical and assessment strategies focus on the prior knowledge, skills, attitudes, and beliefs that students bring into the class. They are also designed to empower students to take charge of their own learning; and encourage classroom processes that involve cooperative and peer-supported hands-on activities.

Competencies-centred: How well students learn depends on how strongly the methods of teaching, the learning activities, and the assessment strategies are aligned to the competencies that students are expected to develop in each grade. Thus, the sample pedagogical processes and assessment strategies are aligned to both the content domains and the cognitive skills indicated in competency statements.

Assessment-centred: Since assessments are an integral part of the pedagogical process, the LF shares strategies for formative assessments. These strategies have been designed to help students modulate their understanding of their own learning, and help teachers adaptively refine their pedagogical approach based on student performances. To increase the possibility of reflecting the individual capacities of students, these strategies are designed to allow multiple modes of assessment, including portfolios, project work, presentations, as well as written and oral assignments. They are also designed to include peer assessment, where students assess the work of their peers against pre-decided assessment criteria.

Content domain/ Chapter name	Materials (Is Matter Pure)	
Grade	Grade IX	
Learning Outcome	Describes different methods of separation to get individual components from a mixture	
Indicator	Explains the separation of sand and water using filtration	
Cognitive level	Applying	
Thinking process	Relate	
Difficulty level	Low	
Marks **Time**	1 1 min	
Item stem	Sea salt is a mixture of sand and sodium chloride. Sand is insoluble in water and hexane. Sodium choride is soluble in water but not in hexane. What is needed to separate sand from sodium chloride? 1. Filter paper 2. Fractionating Column 3. Hexane 4. Water	
Correct answer	1 and 4	As water is the only solvent that will dissolve sodium chloride.
Distractor 1	2 and 3	A fractionating column is not needed to separate this kind of mixture. This apparatus is used to separate miscible liquid mixtures.
Distractor 2	1 and 3	Hexane is not a solvent for either sand or sodium chloride. The student does not understand the importance of the solvent for separating the mixture.
Distractor 3	2 and 4	A fractionating column is not needed to separate this kind of mixture. This apparatus is used to separate miscible liquid mixtures.

Fig. 4. A sample select response question.

<table>
<tr><td>Content domain/ Chapter name</td><td>World of Living/ Control and Coordination in Animals</td></tr>
<tr><td>Grade</td><td>Grade X</td></tr>
<tr><td>Learning Outcome</td><td>Analyses and interprets data/graphs/figures relating to the prevalence of diseases resulting from the failure of control and coordination mechanisms.</td></tr>
<tr><td>Indicator</td><td>Analyses and interprets data/graphs/figures (district/state/national) relating to the prevalence of diseases due to hormonal imbalances and failure of similar mechanisms (like, diabetes, goitre, gigantism, and dwarfism)</td></tr>
<tr><td>Cognitive level</td><td>Applying</td></tr>
<tr><td>Thinking process</td><td>Interpret information. Explain.</td></tr>
<tr><td>Difficulty level</td><td>Medium</td></tr>
<tr><td>Marks
Time</td><td>3
5 min</td></tr>
<tr><td>Item stem</td><td>The graph below shows age-specific prevalence of diabetes in males in the years 1990 and 2016.


Which age range shows the highest prevalence percentage of diabetes for the year 2016?
What is the increase in prevalence percentage for the age group 25-29 from the year 1990 to 2016?
Explain the requirement of artificial insulin for diabetic patients.
Image source: https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(18)30387-5/fulltext#seccestitle10</td></tr>
</table>

Marking scheme

Part	Mark	Answer	Further information
a.	1	For 2016 Age range: 75-79	
b.	1	Increase in prevalence percentage from 1990 to 2016 for age group 25-29: 0.4%	
c.	1	Insulin is a hormone produced in the pancreas. It helps regulate blood sugar levels in the body. When this hormone is not secreted in sufficient amounts, the blood sugar level rises and has harmful effects. Blood sugar levels in people who suffer from a malfunction of the insulin release mechanism are controlled through artificial insulin injections.	Similar explanations shall be accepted.

Fig. 5. A sample constructed response question with its marking scheme.

it also recommends that teachers choose a marking scheme that is aligned to the cognitive level of the assessment item. So if an item is designed to test the application of a concept, the marking scheme needs to illustrate the many possible responses that could represent its application. The LF provides some sample responses for its sample assessment items—these responses are meant to be indicative since including an exhaustive summary of all possible responses may not be possible.

Parting thoughts

As teachers, each one of us is gradually moving toward new and engaging ways of teaching and learning aimed at preparing our students for a rapidly changing world. One of the ways that we can do this is by helping them build competencies such as asking questions, testing hypotheses, communicating the results of investigations, collecting data, justifying assertions, etc. This framework aims to help teachers to make this shift in their classroom by redefining the curriculum in terms of Learning Outcomes and Indicators. As of now, the framework is hosted on the CBSE website and can be downloaded for use. A set of teachers and administrators nominated by CBSE schools found the framework to be helpful to educators in the development of scientific temper, freedom from fear and prejudice, and respect for human dignity and equality.

Key takeaways

- Many policy documents, including the NEP 2020, recommend a competency-based approach to education as a way to develop sensitivity, evidence-based thinking, scientific temper, and innovativeness in students.
- While the NCERT has identified and published Learning Outcomes (LOs) for Grades VI-X, several teachers find these abstract and disconnected from their practice.
- The science Learning Framework (LF) is designed to help teachers see connections between these LOs the science curriculum, pedagogical principles of teaching science, and the assessment of science learning.
- By redefining the curriculum in terms of LOs and Indicators, the LF can enable teachers to build competencies such as asking questions, testing hypotheses, communicating the results of investigations, collecting data, justifying assertions, etc., in students.
- A select group of teachers and administrators who have reviewed the LF have found it to be helpful to educators in the development of scientific temper, freedom from fear and prejudice, and respect for human dignity and equality.

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