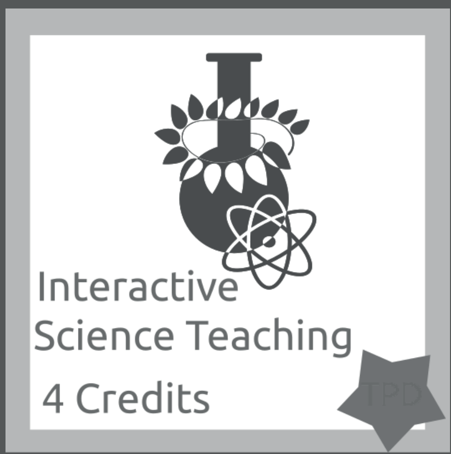
# Reflective Teaching with ICT

## S03 Interactive Science Teaching
## Coursebook

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CONNECTED LEARNING INITIATIVE

# SCIENCE

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# SCIENCE TEACHER COURSEBOOK

## CONTENT

# Unit 01: Nature of Science

# Session 02: What Is Science?

## 1 Nature of Science

*-Arvind Kumar*

***Abstract*** Understanding the nature of science is now widely seen as an important aim of science education. This article discusses the reasons for introducing 'nature of science' in the school science curriculum, the changing views of the topic and the ways of teaching it.

**Keywords: Nature of science, new perspectives, inquiry and history-based approaches**

Science textbooks begin by asking 'what is science' but answer it too briefly. Then they get to the main business, which is science content—facts, laws and theories. The short answer to 'what is science' goes like this: Science involves making systematic unbiased observations of nature, doing careful experiments and drawing logical conclusions to find out the laws of nature. Hypotheses and theories are suggested to explain the known observations (what has happened) and to predict phenomena (what will happen). If the predictions come true, the theory is confirmed. Science bows to no authority except facts and logic. Science is objective, meaning that whether something is true or false does not depend on a person's beliefs but only on facts.

This answer seems good enough. So why should we teach the nature of science (NOS) when there is so little time to finish the 'more important' parts of the subject?

### Why Teach 'Nature of Science'

To work out why we should teach nature of science (NOS), let us first think of the purpose of teaching science at school. Why is science a compulsory subject up to the end of secondary school? How many of all students have any use for it? Most students do not go to college after school; many stop formal education. Of those who go to college, only a small proportion goes to the science stream and the majority goes to arts, commerce and other branches. Do all these other students need science content knowledge? If they don't, what is it about science education that is useful to them?

Clearly, the goals of science education cannot be only to give science content knowledge to all students. What else might they be? There are many opinions on the goals of science education, some based in ideology. But most agree that creating an informed science public is a principal goal.

The 'informed science public' is one that has an understanding of what science is, what the methods of creating scientific knowledge are, and what science has to do with technology and society. Science and technology matter in every area of life in today's world. To make choices and form opinions in such a world, people must have a basic understanding of the benefits and risks of modern technology, its impact on our health and environment and so on. Another goal is that every educated person should appreciate that work done in the sciences is as great as the finest works of art, literature and other human achievements. Science can promote a rational view of life, meaning that we believe things happen for a reason and that we can understand that reason by thinking systematically. (Right now, this goal seems difficult to achieve.)

These and many other goals of science education are sometimes called 'science and technology literacy'. This term and its definition changes, but one thing is clear. The goals of school science education give us the reasons for teaching NOS.

Would the teaching of NOS be at the cost of teaching science content knowledge? If we do that, wouldn't we put at risk the development of future scientists and science in the country? And even if we paid that price, will the teaching of NOS be much use for the majority of students, that is, students who will not study science after school? Many teachers and scientists ask these questions.

These questions come up because the place of NOS in science education and the way to teach it are still not clear. Let's clarify those two points. First, the place of NOS in science education. NOS is not meant only for students who will stop studying science after school. Science students need it, too. It is wrong to think that science students need to study only the content of science. In fact, educators believe that NOS can deepen the understanding of science content and so help all students. Science education researchers have studied students' beliefs about the nature of knowledge in a subject and found that these beliefs have an effect on how well they learn that subject. See, for example, Redish (2003) and the references in it.

Second, the way to teach NOS. Teaching NOS does not mean teaching theories and abstractions out of a separate chapter in the textbook. Nor does it mean making time for teaching NOS by cutting into science content teaching. NOS is best taught together with science content, in the context of science topics. Before we see how that might be done, we must first broadly agree on our views on NOS.

**Nature of Science: Evolving Perspectives**

Philosophers and others have debated the nature of science all through history and continue to do so even today. As science has progressed, particularly in the last four centuries, so have our ideas about the nature of science. In the sixteenth and seventeenth centuries, when Galileo, Descartes, Kepler and Newton were creating modern scientific knowledge, Francis Bacon was describing how that knowledge was created, which is called the scientific method. The introductory paragraph of this article is taken from Bacon's ideas about NOS. Bacon's main idea is that science uses unbiased observations and controlled experiments to form tentative conclusions (inductive generalisation) about the laws of nature. He understood that the new method would do very well in not only predicting what will happen but also controlling what happens.

In the beginning of the twentieth century, an influential group of philosophers of science decided to describe the scientific method more exactly. Briefly, they said that science could only work with 'meaningful statements, meaning statements that were obviously true or could be checked for truth. Theoretical terms like 'atom', 'gene' or 'valency' could be used to understand things. But scientific statements had to be about something observable about these things. By this rule, poetry has no meaning, though it does no harm. Abstract philosophical statements are worse because they, too, have no meaning but claim to be true! This view of science is called logical positivism and has a moderate version called logical empiricism. However, all of science cannot be expressed in the kinds of statements logical positivism allows.

Another attempt at clarifying the scientific method is the philosophy of Karl Popper. Popper wanted to separate science from pseudoscience, or bogus science. He is famous for his falsification criterion: A theory is not scientific if there is no way to prove it false. Good scientific theories make definite predictions that can be proved true or false. If the prediction is proved true, the theory is not confirmed; it is only that it is not proved false yet. This is good science. By contrast, pseudo-sciences do not make clear-cut predictions you can test. Anything that happens can be called proof of the theory. Popper said that science should 'stick its neck out', meaning, take the risk to make bold new predictions and suggest experiments that can falsify a theory. Popper was inspired by Einstein's work, and his ideas ring true to scientists. He is often called the scientists' philosopher.

In the 1950s, Quine examined all these ideas and presented his own. He argued that single statements, each taken by itself, could not be proved true or false because they are all related in a theory. A scientific theory is made up of many assumptions and conclusions, all tied together in complex relationships. Quine called for a holistic theory of meaning and testing. Such a theory would make rules about the meaning and testing of scientific ideas by taking into account the relationships between statements (parts) and theories (whole).

One problem in defining the scientific method is that doing science has two parts. One is the creative part when scientists think of—or dream up—explanations of things. The other is when they give proof of their ideas by strict rules. A philosophy that sees science as a rational activity that has to keep these two parts separate. The creative part is the business of psychology or sociology, which are about how human beings think and in what kinds of conditions. Because philosophers of science left out the creative part, their idea of the scientific method was based on only half the story of doing science. They described what the scientific method should be rather than what it actually was.

Around the 1960s, Thomas Kuhn's now famous book The Structure of Scientific Revolution began to change our ideas of the nature of science and how science progresses. Kuhn studied some important points in the history of science (such as the Copernican revolution) and came to the following conclusions: Scientists normally work within the accepted ideas of their times. They are conservative up to a point and do not give up their theories even when some results are not as expected (anomalies). However, when the unexpected results are quite definitely true and more and more show up over time, scientists begin to raise questions about the accepted ideas. Many alternative ideas are suggested, out of which some promising new ideas get the support of many scientists. This may be because some highly respected scientists have supported them. The new ideas are accepted become the new normal ideas, and scientists settle down to work out their details and applications. The key point in Kuhn's philosophy is that the new accepted ideas are not chosen purely because of facts and reasons but at least partly because other scientists accept them. The accepted ideas are taught in schools and colleges, so that the next generation of scientists accepts them. Not everybody agreed with Kuhn. Lakotos totally disagreed with Kuhn's idea that scientific progress was not mainly rational and offered his own theory of competing 'research programmes'. Feyerabend said there is no clear method in the way science evolves and 'anything goes'. His book Against Method praises creativity in science and criticises the routine, dull activities of normal science.

Kuhn's theory, whether good or not, brought sociological ideas to the philosophy of science. In fact, some sociologists held that the philosophy of science could tell us nothing about NOS, only a detailed study of the way scientists work would. We will not go further into this topic. But we now better understand how science grows in a particular society and culture. Strong social institutions of science (scientific societies in Europe, such as the Royal Society) that encourage open and democratic discussion, peer reviewing of research and the idea that scientific laws belong to everyone are some social aspects that matter as much to scientific progress as the talent of individual scientists.

Here are some ideas on NOS taken from all these philosophies. First, science does not just draw conclusions from data (observations, results of experiments) but sometimes uses creative ideas far beyond the data. Some very successful theories were suggested not because of the data but because they matched other theories, gave better explanations or gathered many theories into one. Second, data does not come in some pure form; scientists decide what data to collect based on theories. (Science is still objective in spite of this.) Third, the same data may confirm different theories about the same things, which means that it cannot strongly confirm any one of those theories. Fourth, science is about thinking, but not only that; it is also about agreeing with fellow scientists. Fifth, science, technology and society (STS) affect one another. We must watch out for the risks in scientific practice and unthinking use of technology.

This brief overview is meant only to give a flavour of the topic; it admittedly does not capture the many finer points of the philosophy of science. See, for example, Godfrey-Smith (2003) for a more detailed explanation of this topic and for references to the classics mentioned here.

**Nature of Science: How and What to Teach**

Keeping in mind the historical and current debate on NOS, let us try to define what students should learn about NOS at school. Obviously, the philosophical points are not for the classrooms. In spite of the different views of NOS, most thinkers agree on a few essential ideas that young students can learn. We recommend reading the New Generation Science Standards (NGSS, 2013) developed in the US and similar objectives written elsewhere, for example, Pumfrey (1991), Osborne et al (2002) and Taylor and Hunt (2014). The list below has the objectives that most thinkers in the field agree on. More details on NOS objectives are in the references cited. For a much deeper study of the subject, see Erduran and Dagher (2014).

**Nature of Science Objectives (Summary)**

Students should appreciate that

Scope

Science tries to describe and explain the physical world based on data from observations and experiments (empirical evidence). Some areas of knowledge may be beyond its scope.

Methods

Science uses a variety of methods; there is no one universal method of science. Science does not involve induction (generalisation from data) only. Creativity and imagination are equally important in suggesting explanations of data (hypotheses and theories).

Observations and experiments are often not enough to determine a theory.

Science involves expert judgements, not only logical deductions. So, different scientists can reach different conclusions.

Social aspects

Science is cooperative in that many people work together, with some individuals playing an important role. Social institutions with open debate, peer reviewing and knowledge belonging to everyone are necessary for the growth of science. Science and technology may lead to conditions and problems that must be handled in different ways depending on the society and culture where they occur.

Scientific knowledge

Science keeps changing and growing, especially when new empirical evidence comes up. The essential ideas at the centre are more definite while new ideas being researched are more likely to change.

Finally, the most important but difficult question: How should we teach NOS? Content alone is not science education. This is not a new idea as the history of curriculum reforms shows. Around the 1970s, some educational reforms gave more importance to the processes of science than to its content. The processes of science are observing, measuring, classifying, analysing, inferring, interpreting, experimenting, predicting, and communicating and so on. This approach was carefully examined. Some educators disagreed that there is a set of processes common to all sciences. See, for example, Miller and Driver (1987).

There has been a broad agreement on an inquiry-based approach to science learning and teaching. This approach is based on the constructivist philosophy. It has process-based learning but also includes posing questions, critical thinking, giving evidence-based explanation, justifying it, connecting it to existing scientific knowledge and so on. It recommends learning science in a way that is like the way scientists do investigations. Inquiry tasks present a question and ask for an evidence-based explanation. The tasks are simple for younger children and detailed and complex for older students. The tasks can focus on science content or STS questions. Inquiry tasks can ask students to think about the inquiry mode itself and, in this, cover NOS educational objectives. Refer to a critical account of the inquiry approach, including its relation with NOS, in Flick and Lederman (2006).

Another approach uses the history of science (HOS) to teach NOS. This again is not a new idea; see the excellent book by Holton and Brush (2001). This approach has certain advantages. HOS has human stories that bring alive science and get students' interest. It often has parallels with students' own ideas and helps to correct those ideas. Learning about how the science we know today arose out of

many alternative ideas at different times in history can make students think critically. HOS is a most natural setting for learning NOS. Refer to a comprehensive Handbook brought out recently on this issue (Matthews 2014). As Lederman (2006) has argued, NOS objectives are mainly to do with cognition (learning and thinking) and can be assessed. Instruction needs to spell out these objectives; they can't just be covered under something else. This is true whether we use an inquiry or a history-based approach in teaching NOS. A whole range of inquiry tasks and HOS-based descriptive pieces need to be developed if we are to improve students' ideas of NOS.

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# Unit 2: Pedagogical Content Knowledge

# Session 2: Fostering Science Thinking In Classrooms

## 2 Representations and Reasoning

***-Shamin Padalkar***

When we learn science, we mainly do two things: We learn some new information and learn how to use it. For example, we may learn about viruses and bacteria, and based on that, we learn to explain why we fall ill and how certain illnesses can be cured. So thinking is constituted of two things: mental representations (information) and mental processes (how to use information to draw inferences). This analogy is taken from computer where a computer stores some information (representation) and works on it (processes it) according to a given programme to return an output (inference). Let us take a closer look at the human mental representations and processes.

### Instances and Rules

We come across several observations of nature from childhood. For example, we see the rising of the sun, the changing shapes of the moon, the flowering of trees, water flowing and so on. We gradually start seeing patterns in some of the phenomena. For example, a child may notice that the sun rises from a certain direction every day; an adult might give the label 'east' to that direction and the child infers 'The sun rises in the east'. Similarly, another child might observe that several mango trees have blossomed and that they had blossomed around the same time last year. The child may come up with the rule 'Mango trees blossom in spring'. We make many simple observations and derive rules based on them. This kind of reasoning is called 'inductive reasoning'. In inductive reasoning, we usually generalise from several observations. The generalisations hold true until we find contradictory evidence. For example, as a child, I used to think that fresh leaves are green until the day I came across a garden plant with red leaves. I still remember how amazed and puzzled I was.

At an advanced level, we systematically study the relationship between two quantities and try to come up with a rule. For example, we may notice that a steel tiffin box expands due to heat (so that the lid doesn't fit) and we may explore to find out whether all the substances expand when heated. We may conclude that metals always expand when heated (even mercury!), other objects may or may not (e.g., water at a certain temperature). Further, we may study how the time period of a pendulum changes as we change the mass of the bob, the length of the string or its amplitude. (And guess which rule we come up with!) Such rules are called 'empirical' rules, and the process through which we arrive at them is called 'empirico-inductive' thinking.

However, we can never be sure about the rules we derive since there is always a chance that we will come across a contradictory case. So we always propose or 'hypothesise' these rules. Coming up with hypotheses and finding ways to test them is one of the most remarkable features of the scientific method (remember Article 'Nature of Science' in Unit 1). In fact, once a hypothesis is proved for the first few cases, scientists always try to find ways to disprove it, not to confirm it! You may find many confirmations, but one piece of contradictory evidence is what takes science ahead! Thus hypothesis testing is crucial in scientific thinking—may it be in our regular lives may it be in advanced science labs!

**Concepts**

Next simplest unit of representation could be 'concept'. We use concepts to categorise the world around us. For example, take the concept of a 'dog'. A child watches several real dogs, maybe some pictures of dogs, and abstracts out the essential qualities of a dog. So, from a few concrete instances, we abstract a concept. As you can guess, most children are capable of doing it by the age of one and a half years. Many of their first words are, in fact, concepts such as 'cow' and 'flower' and 'chocolate'.

The first level of difficulty arises when children are required to deal with concepts of objects which cannot be seen directly. For example, 'air' cannot be seen, but we infer its existence through other perceptual experiences (e.g., seeing dust raised by the wind) and through indirect methods (e.g., bubbles form when we dip an empty glass in a bucket of water). We need to be careful when we teach such concepts. We cannot teach them until children are old enough to make inferences. We need to give them a number of concrete experiences to infer concepts and what exactly they represent. Therefore, primary and middle school science classes should include many carefully designed activities to help students to understand such concepts.

The next level of difficulty arises when children are required to work with concept that do not refer to concrete objects. For example, concepts such as energy, force, acceleration, conductivity, chemical bond, evolution and so on. Science is full of such concepts. We have created these concepts so that we can understand how nature works. Empirically, it is seen that young adults (12 years onwards) are capable of understanding these concepts. Therefore, these concepts are rightly introduced at the high-school level. It is difficult to understand the meanings of these concepts at younger ages. One cannot show objects or instances that illustrate these concepts. But being able to understand and work with these concepts is crucial to scientific thinking. As teachers, we need to know which concepts are difficult to understand and how we can make our students understand and appreciate them.

**Logic, or Deductive Thinking**

Of course, knowing concepts alone doesn't take us very far. We need to know how to use those concepts to draw inferences. Consider the following sentences:

Fish stay under water to breathe.
Shark is a kind of fish.

We can easily infer that

A shark stays under water to breathe.

This is called deductive reasoning. In science, we combine the facts we know and derive new information. For example, when we derive Kepler's laws from Newton's laws, we are using derivations. In fact, all the derivations we learn during higher grades use deductive reasoning. Children as young as

3 years old can use simple deductive reasoning. As the reasoning becomes more complex (combines more information), we may not be able to arrive at the inference by spontaneous mental processes, or 'do it in the head'. We use paper and pencil to write down equations to free up some of our memory space to do the processing. Thus, representations such as equations and symbolic logic[1] are used for advanced deduction. Students of science need to learn the conventions of representations and the rules to use them. It is one of the most common skills scientists use. We should try to teach our students this skill rather than a specific derivation which they will learn by heart and reproduce in the exam. Students will take small steps in the beginning so it may seem like a time-consuming process, but actually, it is not! Once they acquire the skill, they will be able to derive any derivation on their own, so we will later save the time spent on teaching individual derivations.

**Mental Images**

But do concepts and deductive reasoning encompass all scientific thinking? No, concepts are only one kind of mental representation. What do you remember when I say 'a pearl'? Most probably a mental image of a pearl would be evoked. A mental image would include a pearl's colour and shine (visual qualities) and its approximate shape and size (spatial qualities). It should be noted that mental imagery is not restricted to 'visual' mental images; we experience imagery for other senses, too. For example, the word 'tamarind' would evoke our gustatory (related to taste) imagery, 'cuckoo' would evoke auditory (related to hearing) imagery and 'jasmine' would evoke olfactory (related to smell) imagery. Experiencing the sensation produced by objects without the objects being present is called mental imagery. Visual imagery is the most studied area among all. What could be other kinds of imagery?

What do mental images have to do with science? Do you know how Kekule discovered the structure of benzene? He knew that there were 6 carbon atoms and 6 hydrogen atoms in benzene. But he couldn't imagine the structure holding these atoms together; cyclic structures were not known at that time. He day-dreamed an Ouroboros (snake biting its own tail, see (Figure 1), and then it occurred to him that it could be a ring! This opened the world of cyclic organic compounds!

1 In formal logic, we represent propositions by letters such as P and Q and combine them with logical operations (e.g., AND and OR) to check whether the inferences are true or false.

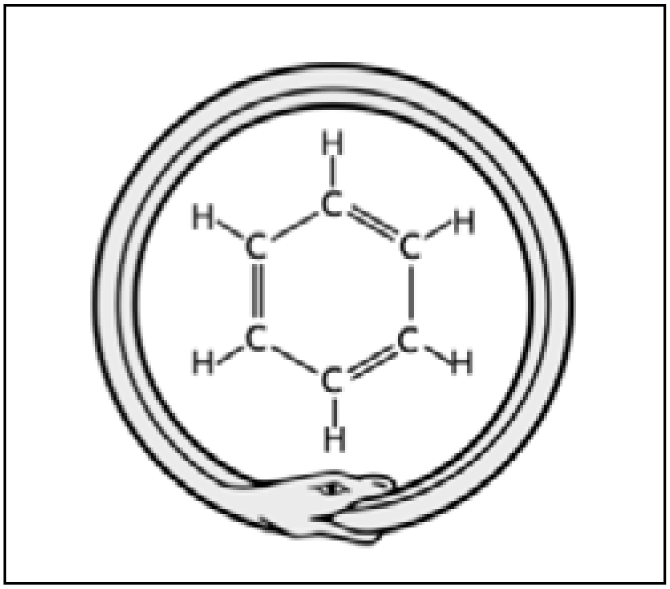

*Figure 1: Ouroboros (snake biting its own tail) and the structure of benzene*

Thus, mental imagery plays an important role in scientific discovery. It also plays a crucial role in learning science. Suppose we are teaching the digestive system. We can use a diagram, a colour picture, a 3-dimensional model or if possible a computer animation. All of these are representations of reality. Most students will never see the real digestive system, except those who opt for higher education in medicine[1]. From all the representations, students have to form an image of the digestive system for themselves. This image supports their understanding when they try to explain how food is digested, what could be the causes of acidity and how acidity can cause stomach ulcers.

Therefore, we should encourage students to draw and describe what they see (e.g., different shapes of leaves) and what they understand (e.g. digestive system). Pay attention to the conceptual understanding represented through their drawings rather than neatness. While drawing the digestive system, a student who draws rough shapes of the organs with the correct connections between them has a better understanding than one who draws accurate shapes of the organs but shows incorrect connections between them. Expose students to different images of the same thing so that they form accurate and richer mental images (see Figure 2). Help them to see similarities (e.g., spirals on the shell of a small snail, a sunflower head, a whirlpool and a galaxy) and patterns (e.g., hexagonal cells in honeycombs, merosity number of petals) among flowers).

1 Seeing the real digestive system, along with rest of the organs and blood vessels and blood, may not really help students understand the structure and functions of the digestive system.

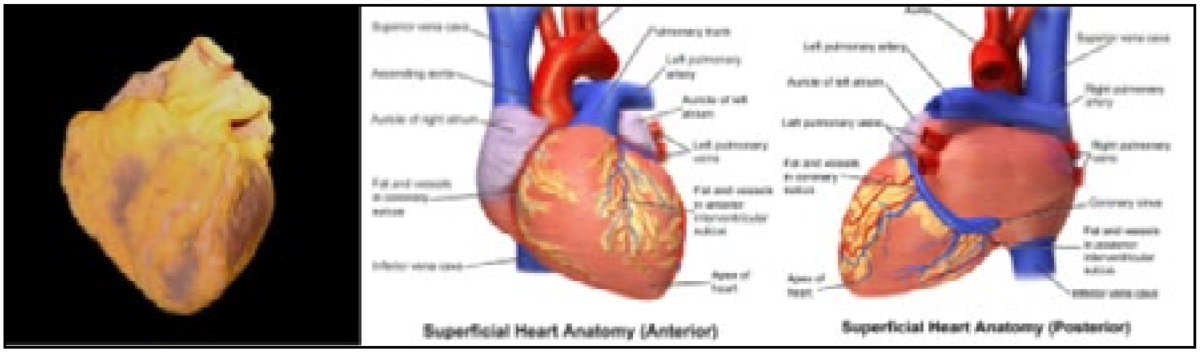


*Figure 2a: Photograph of a human heart By Jebulon - Own work, CC0, [https://commons.wikimedia.org/w/index.php?curid=57065825](https://commons.wikimedia.org/w/index.php?curid=57065825)*

*Figure 2b: The human heart viewed from the front*

*Figure 2c: The human heart viewed from behind*

### Mental Models

A more complex kind of mental representation is known as a mental model. A mental model consists of several related concepts and images. For example, a mental model of the solar system would include its rough image (e.g., the sun at the centre and planets moving around it). It may also include concepts such as the sun, the planets, satellites, asteroids, comets; the relations between them; information about their positions, motions, shapes, sizes and masses and many other things. We may have images of parts of mental models such as particular planet or earth moon system and so on. Mental models play a crucial role in developing scientific theories. For example, the model of the nucleus is at the core of nuclear physics, the model of an atom is at the core of the entire field of chemistry, mental models of DNA form the basis of genetics and so on. Mental models can be thought of as forming the skeleton of a theory. Can you think of other mental models which are crucial to a theory?

### Visuospatial Thinking

Recall that concepts are a kind of mental representation and that we use logic to derive inferences from them. Similarly, mental models are another kind of mental representation. The reasoning we use to derive inferences from mental models is called model-based reasoning. For example, astronomers can often predict the timings of solar and lunar eclipses. They can predict the transits of planets, the trajectories of comets (and whether they will come back) and so on. They need to use images, equations and language to do so. Apart from logic, model-based reasoning involves visuospatial thinking. Consider a simple question: How do day and night occur on earth? The explanation would involve an image of the earth and the sunlight falling on it. We can infer that half of earth will be lit and half will be dark at any time. Now, in our minds, we slowly rotate the earth and infer that different locations are falling on the terminator (the line dividing day and night). After half a rotation, the part which was lit will be dark and vice versa. Here, we visualise a situation and mentally simulate it to explain or derive an inference. Thus, visualisation and spatial thinking (together called visuospatial thinking) is an important component of model-based reasoning.

Although both mental imagery and visuospatial thinking are involved in the creative processes of discovery and learning of science there is little emphasis on them in our education system. We teach language and mathematics to our students as tools with which they can think. But not much effort is made to develop visuospatial thinking. Students should be asked to mentally simulate situations such as interlocked gears. This will help them to explain how a bicycle works. This is a first step towards designing a complex system of gears which are used in automobiles and watches. Ask them to visualise a chair from different perspectives. This will help them to read plans when, later in life, they buy a house or design houses and other structures if they choose to become architects or engineers! Encourage them to discover new roads in their locality and take their help while planning a school trip so that they can deal with large new environments in later life!

**Representational Competence**

There are concepts, and there are rules. There are numbers, and there are equations. There are images, and there are mental models. Knowledge is acquired and expressed in many ways. No single form would suffice! For each mental representation, there are multiple external representations. Take 'earth' for example. There are many words to represent it in a single language (e.g., 'globe' and 'terra' in English). (Think of the synonyms of 'earth' in your language.) We use the term 'world' when we refer to the people and nations on earth. We say 'land' or 'ground' when we refer to its surface. At the same time, we know that the earth is a planet. Carl Sagan refers to this planet as a 'Pale Blue Dot'. Many cultures consider it a mother or a goddess. Thus, we use multiple metaphors to refer to it. We have numbers to express its size and equations to express its shape and trajectory. There are multiple diagrams to express different aspects of it (internal structure, a cross-sectional view), different kinds of maps (surface mapped on a plane), and photographs and so on. We should expose students to these multiple representations. This will convey that representation cannot be treated as reality; we need to construct reality from the representations. We should help students to understand that some of the representations may be more suitable for our purpose than others. (We would never use the structural diagram of the earth to find the distance between two locations. For this purpose, the map is the best representation.) Thus, representations have strengths and limitations. To succeed in science, students should be able to choose the correct representations, translate them from one to another form and combine them if necessary.

**Credits / Attribution**

Figure 1: Ouroboros

*Image by Haltopub - Own work base sur Benzene Structural diagram.svg et Ouroboros-simple.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=29661966*

Figure 2: Human heart

*Figure 2a: Photograph of a human heart By Jebulon - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=57065825*

*Figures 2b and 2c: Images by Blausen Medical Communications, Inc. - Donated via OTRS, see ticket for details,*

*Figure 2b: https://commons.wikimedia.org/w/index.php?curid=26986380*
*Figure 2c: https://commons.wikimedia.org/w/index.php?curid=30111372*

“Representations and Reasoning” by Shamin Padalkar for Tata Institute for Social Sciences as given.

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# Unit 03: Principles and Practice of Science Education

# Session 01: Inquiry in Science classrooms

## 3 Creating a culture of scientific inquiry in the classroom

***- Aisha Kawalkar***

Many changes to improve science education have been suggested around the world over the past decades. At the centre of these reforms is the idea that science should be taught in the same way that scientific work is done (Minner, Levy, and Century, 2010; National Council of Educational Research and Training [NCERT], 2005; US National Research Council [NRC] 1996, 2012). Science teaching should start with questions regarding the world around us, get students to wonder, investigate, gather evidence and use it to explain the phenomenon being studied. But this is not how science is usually taught in classrooms. Why have we not changed the way we teach science? According to researchers, some of the reasons are the kind of learning environment created, the way students and teachers talk in class and what teachers believe and how these beliefs influence their teaching (Ball and Cohen, 1999; Chen, Hand, and Norton-Meier, 2016; Hanrahan, 2005; Kawalkar and Vijapurkar, 2013; Zhai and Tan, 2015).

Let us take a close look at one classroom and then think about what happened, how the teacher and students exchanged ideas. It is a Grade 8 classroom and the topic is classification.The teacher's goal is to make students understand classification in biology with 'fish' as an example, what features do fish and only fish have or what makes a fish a fish?

**Teaching in Classroom 1**

Teacher: Can you recognise this? (Making the shape of a fish with her hands)

Students: Fish!

Teacher: How can you say it's a fish?

Students: Fins.

Teacher: So, my moving thumbs are showing fins. Are they in a pair? (Continuing to show a fish with her hands)

Students: Yes.

Teacher: Yes, they are two. And?

Students: Streamlined.

Teacher: Yes. Now tell me, is this a fish? (Showing a Bombay duck or bombil fish)

Students: Yes.

Teacher: How can you say something is a fish?

Students: It has fins, gills...

Teacher: You can say paired fins. Fins are for swimming, isn't it? Fish are aquatic. Also they have long, streamlined body and gills, with or without operculum. (Showing another fish) Again, this is a fish. There are differences, but there are common features that something must have to be called a fish. (Showing a prawn) What about this? Is it a fish?

Students: Prawn.

Teacher: Is it a kind of fish?

Students (a few): Yes.

Teacher: It is not a fish, ok? Because it does not have any paired fins. It's a creature having tentacles, five pairs of legs and sections in the lower body (pointing to the specimen). So, prawns are not fish. Is that clear?

Students: Yes.

Teacher: It's not a fish because it does not have...?

Students: Paired fins, streamlined body, gills.

The teacher explains how a seahorse is a fish and why a jellyfish is not a fish. She has brought specimens of these organisms and of several kinds of fish for students to see. Later, she explains different inner and outward characteristics in detail, such as how the streamlined (spindle-shaped) body shape helps in swimming and the differences in fishes with bones or cartilages.

The teacher in this class began the lesson in an interesting way, by making a fish with the hands and asking students what it is and why, which prepared students for the lesson on fish and got them interested. She asked questions to keep students talking to her instead of just listening. She had taken the trouble to bring specimens and used them to show the qualities that decide which animal is a fish.

Now let us look at a lesson on the same topic in another classroom.

**Teaching in Classroom 2**

Teacher: I want you to draw something, will you? (Students nod and seem interested.) Draw a fish. A simple drawing will do.

The teacher notices a whale and a starfish among the drawings. Some are just sketches of the general idea of a fish, not a particular fish. So she asks students to name a fish. Among examples of fish are mentioned some other creatures like blue whale and octopus.

Teacher: Are they all fish? Why or why not?

Student 1: Whale is a mammal.

Student 2: Octopus is a mollusc.

Teacher: What features do you see in an animal to call it a fish?

Students: Streamlined body, fins.

Teacher: What about a seahorse? Is it a fish? It has a very different body shape. (She shows the specimen she has brought to the class.)

Some students say it is a fish, and others say it is not. The teacher lets them observe the specimen, and students say that the seahorse does have gills and fins. She then shows them a specimen of a prawn and asks the same question.

Student 3: It has no gills.

Student 1: I am saying it is not a fish because it has a hard shell and not scales like fish.

Teacher: Hmmm.

Student 4: It doesn't have fins either.

Teacher: Let me show you. Prawns do have gills to breathe underwater (shows the underside of the prawn giving students a glimpse of gills).

Student 5: There is no opening for gills, like in fish. It is covered by a thick, nail-like shell on top.

Teacher: Yes, that is called the carapace, like in a crab...

The teacher realises that only a few students are answering and many are confused. She tries to make the point in another way. She shows some specimen of fish she has brought.

Teacher: (Pointing to the Bombay duck and the pomfret, two very different looking fish) Now tell me, why are they both fish?

Students came up with several criteria, or points to check in order to decide if an organism is a fish – fins, gills, snout, and peculiar tail. The teacher gives a counterexample, meaning an example of what is not a fish. She mentions the prawn, which has all the points students have named but is not a fish. So, students add the criteria of streamlined body, scales and lateral line organ. In the next class, the discussion goes on. The teacher gives more counterexamples to check the criteria. Students add more criteria so that the counterexamples are not fish.

Teacher: Do all fishes breathe only through gills?

Student 6: Lungfishes can breathe through lungs also.

Student 7: Dolphins breathe through blowholes.

Student 1: Dolphin is a mammal.

Teacher: But why is it not called a fish?

Student 8: It gives birth to young ones; it does not lay eggs.

Student 3: Shark also gives birth to young ones though it's a fish.

Student 8: Dolphin is warm-blooded.

The teacher briefly explains the term 'warm-blooded' and that most fishes are 'cold-blooded'. Students have questions: Is jellyfish a fish? If not, why is it called a fish? A tadpole has many of these features. Can we call it a fish? As the discussion goes on in the next class, new criteria to decide what is a fish come up, such as fish being cold-blooded, having a backbone (unlike jellyfish and starfish) and gills throughout life (unlike the tadpole). The teacher tells them a little about the early history of how fish were classified. Sixteenth century scientists who started to explore the oceans had called many aquatic creatures' fish. Today, scientists think of fish as a diverse group. Finally, the teacher summarises the criteria, or the points, to decide which animal is a fish and compares them with the standard definition of fish: an aquatic creature that is a cold-blooded vertebrate and has gills throughout life and limbs in the form of fins. Comparing these two examples, we can think about the differences in the way the learning went on and the way teachers guided the class discussion.

**Working out the explanation**

The most important difference between the teachings in the two classrooms was the way students came to know the answer to 'what makes a fish a fish?' In the first classroom, the teacher asked the question but then very soon gave the answer herself. In the second case, the students came up with an answer, with the teacher guiding and supporting them in various ways. People think that actively learning science means doing a lot of activities and experiments. But what really makes science learning active is trying to make sense of observations and experiences and arriving at explanations based on evidence and argumentation (Abell, Anderson, and Chezem, 2000; Cobern et al., 2010). In both the classrooms, students observed and compared different specimen of aquatic creatures. In the first classroom, it was just an extra activity. In the second, it was an essential part of the lesson. Discussion in the class was based on students' observations from the activity and discussion in turn led students to more observations.

**Teacher's questions**

In Classroom 1, the teacher kept the class interactive through questions. But students were not really sharing ideas, or having a 'true dialogue' as Lemke (1990) would call it. The teacher and the students were not trying to understand each other's position. In Classroom 2, by contrast, the teacher always tried to understand what the students were thinking. She asked them to explain their answers and to give reasons for what they said. She helped them to speak their thoughts clearly and think about how they and others were thinking and drew their attention to what they had missed.

These two teachers' questions had different aims. In the first case, the teacher asked questions to find out what students knew. In this kind of teaching, the emphasis is on students giving the correct answers. In the second case, the questions did many things as we saw above. Because of this difference in questioning, students learnt in different ways in the two classes. This difference showed up in many lessons during the time we studied these classes (Kawalkar and Vijapurkar, 2013). In the first case, the teacher proceeded along these steps:

(1) Get students ready for learning – getting students to pay attention, checking what they know

(2) Give the explanation – explaining clearly and correctly

(3) Revise the explanation – giving different examples

In the second classroom, the teacher did the following:

(1) Get students ready for learning – exploring what students know about the topic, their experiences related to it, whether the topic is difficult for them, and also getting students' interest

(2) Generate ideas and explanations – getting students to think on the topic and share their ideas in class

(3) Dig deeper - asking students to explain their answers, give reasons and evidences for them, point out contradictions between answers

(4) Polish students' explanations – showing how different observations are related, giving hints for aspects students may have missed.

(5) Guide the entire class towards the scientific concept – giving a summary of the discussion and comparing it with the standard scientific explanation.

Thus, though the lessons started in a similar way, they went on in very different ways. This was because of the questions and also because teachers handled students' answers in different ways. The teacher in Classroom 1 wanted students to give the correct answer, the one she had in mind. As soon as she got that answer, she moved to the next point. If students gave a wrong answer, she immediately corrected them. She even asked questions in a way that doesn't need an answer, like saying "It is not a fish, ok?" She also asked 'fill in the blank' type of questions, for example, "It's not a fish because it does not have...?" This way, the teacher kept control over what students would say. She was the only one asking questions and commenting on what students said.

Think about how the teacher and the students talked in Classroom 2. Even when students gave an incorrect response — whales and starfish are fish — the teacher was not in a hurry to correct them. She asked more questions to make students think: "Are they all fish? Why or why not?" When an answer was right but sounded as if learnt by heart — like saying "octopus is a mollusc" — the teacher asked the question in a different way so that students would think and answer. Even better, when there was an incorrect answer like "it (seahorse) is not a fish", she guided students to observe the specimen and gave them time to think and discuss it. So, rather than asking questions like in a quiz, this teacher constantly challenged as well as supported students to think of the answers .She used students' answers to take the lesson further.

Effective follow-up questions engage students in higher-level thinking (Chin 2006) and help them to understand the concepts better.

**Students' participation**

The transcripts, or written out talk, from these two classrooms show how students took part in the class. In the first classroom, students gave very short answers, often all of them talking together in a chorus. When the teacher focuses on getting correct information and gives explanations herself, students just give short answers and there is no opportunity for them to reason out their answers. Also, very few students speak up.

In the second classroom, students spoke openly, shared their ideas and opinions and gave reasons for as well as against what was said in the class. Each student thought and spoke for himself or herself, and many more students took part in the discussion. This may have happened because the teacher asked questions that didn't have just one correct answer, allowing students to make guesses and give their personal view. For example, "What features do you see in an animal to call it a fish?" Students did not have to worry if their answer was correct; they just had to say what they thought. The teacher often acknowledged that she heard the answer (e.g., "Hmmm") and sometimes accepted that the answer was right (e.g., "Yes"). Sometimes, a student's answer or question was thrown back to the student or to the class to think about, for example, "What do you think about this?"

In these ways, the teacher in the second classroom respected and valued what students said. As a result, students could not only talk freely with the teacher but also responded to what other students in the class said. Notice how, towards the end of the lesson in Classroom 2, students responded to each other, either supporting or presenting a different view. More interestingly, students' did not just answer questions; they started a discussion with their own questions and comments. The classroom 5 transformed into a community of learners. The teacher did not remain the only one to judge what was right and wrong and decide what was learnt. She shared this authority with the students.

**Effects of the different kinds of classroom interactions**

Teachers may not be conscious of it, but they shape the learning environment with the kinds of questions they ask, the way they guide the classroom discussion and activities and the ways of thinking they encourage in the science classroom. These choices not only have an effect on how well students understand the concepts and take part in class but also convey to students, without saying it in words, something about the nature of science and learning science. At the end of each class, students in both the classes were asked to write in a diary what they had learnt that day (Kawalkar and Vijapurkar, 2015). Did the teaching in class have an effect on what students felt they had learnt and how they talked about it? Let's have a look at some parts taken from the students' diaries to find out.

**Diary entries from students in Classroom 1:**

We studied about different types of fishes and shark.

Characters for being a fish – fins, dorsal fin, tail, teeth, eyes, gills, nostrils.

The teacher showed us different parts of fish. We got to know about their characters and habtat.

I learnt about the internal and external features of fish. The sea star is a unique organism.

Does starfish also have parts like other fishes?

Why do we categorise sharks as fish and not as mammal though most of the sharks give birth to young ones?

**Diary entries from students in Classroom 2:**

Today we learnt how to prove that an organism is a fish. It made us very excited. I answered many questions.

Is that the seahorse is a fish? We were asked to reason why it is fish.

We discussed many parts of fish for what we look in any creature to decide if it is a fish or not.

We tried to answer which ones were fish and which were not. Almost all my answers were correct (word cut out by student) We washed the gills and touched them. It was soft and had many filaments. All fishes have gills and fins. They may have a streamlined body but some like the seahorse we saw do not. They can have scales, we touched the scales and saw the rings on them. Scientists can count the rings and know the age of the fish. Fishes get birth [sic] in water, they die in water but from where does air come inside the air bladder (swim bladder) inside them?

In the first case, students wrote about what they learnt mostly in a formal and general way. They said they had learnt "about" something – characters, types, features – which are facts. Many of these were superficial facts, not thought through (for example, "Characters for being a fish – fins, dorsal fin, tail, teeth, eyes, gills, nostrils"). In some cases, the knowledge was incomplete and even wrong. The two questions at the end of the lesson show that students didn't ask these questions in class and were left wondering about them.

When teachers just give facts and explanations, it may make students think that science is simply knowledge to be learned and that this knowledge is obvious truth and not to be questioned. Such an idea of science is found to be linked to memorisation as a way of learning (Edmondson & Novak, 1993; Purdue & Hattie, 1999). This makes many students begin to dislike science, thinking that it is a difficult subject and they can't study it.

By contrast, students from the second group described what they had learned in their own words. This means they had understood the concepts well and their new learning had become a part of their knowledge now. They wrote what they had learnt in the form of a question they were finding out about. Learning came from observing things, analysing and discussing them, not just by listening. Students began to get the confidence that they could learn science (e.g., "I answered many questions") and that they could ask questions and try to learn more than what was taught. (Notice how many questions students asked in the class discussion.) They began to understand that science is a method of creating knowledge by working together to make and debate claims based on evidence and reasoning.

All these ideas were not told to students in class. But they understood them from the way the lessons were taught.

**In conclusion: Teachers as designers of classroom culture**

To do science is to talk about, see, value and reason about the world in certain ways that are shared by a scientific community (Lemke, 1990). In the science classroom, students learn to participate in the language and practices of science through the interactions in the classroom. The teacher is the most important model of how to think and behave scientifically and so plays a significant role in guiding students to form a community of science learners. The type and difficulty level of the teacher's questions, the environment created for students to answer and question freely and the pattern of teacher-student nteractions influence not only what students learn but also their attitudes towards science and their idea of what science is (Ball and Cohen, 1999; Kelly, 2007; Kawalkar and Vijapurkar, 2013, 2015; van Zee et al., 2001).

Perhaps the topic of fish classification was simpler and more familiar to the students compared to many complex and abstract concepts in science. But still, a comparison of these two episodes of teaching from the two classrooms and discussion about them brings out how a science concept could be taught just by giving facts and explanation or by guiding students to work it out for themselves. It also points to the effects these two kinds of teaching leads to. What we learn from studying such analyses can help us make choices about what kind of classroom talk we will promote in our science classes so that students learn better and science becomes interesting and accessible to all students.

**Note**

These two classroom episodes have been published in Kawalkar and Vijapurkar (2015). The analyses in this essay are based on Kawalkar and Vijapurkar (2013; 2015). If you would like to read the journal articles, please write to aisha@hbcse.tifr.res.in or jyotsna@hbcse.tifr.res.in.

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# Unit 03: Principles and Practice of Science Education

# Session 03: ICT in science classrooms

## 4 Science Education in the Information and Communication Technology Era

***-Amit Dhakulkar***

### Introduction

Advances in the field of Information and Communication Technologies (ICT) have taken place at an exponential rate in the last four decades. This development has been with regards to the availability of electronic memory, processing power, and various kinds of software programmes.

Another key factor driving the expanding reach of ICT is the reduction in the prices of ICT equipment and devices. Reduced input costs and growing demand provides economies of scale, making them affordable to huge segments of the population.

Thus, increased processing capabilities, reach and affordability have generated vast potential for growing number of applications, particularly in the field of education. ICT can be used not only to enhance learning in science, it can also radically change the way science is taught. This article examines the several ways in which science education is imparted and how the education processes can be impacted in a major way.

Two broad approaches can be observed in the use of ICT in the field of education. The first is more traditional – it subsumes ICT in present pedagogical practices, maintaining the status quo in the teaching-learning processes. Many ICT based programmes tend to follow this approach which is why they are also called Computer Based Tutorials (CBTs). A CBT tries to replicate what happens in a traditional classroom. Textbooks converted literally into a digital format are typical examples. The present article avoids references to such examples.

The second approach is based on the principles of constructionism, as proposed by Seymour Papert. Constructionism overlooks established practices and instead, focuses on the immense potential of ICT, allowing learners to actively construct knowledge by constructing tangible things. In Papert's own words:

> "Constructionism–the N word as opposed to the V word - shares constructivism's connotation of learning as *building knowledge structures* irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe".

Keeping this idea of constructionism in mind, we look at tools which enable and empower learners to "build knowledge structures" when they are engaged in constructing a public entity in the context of science.

**Linkage between science and science education**

Scientists use the best tools and technologies in ICT available to them to collect and visualize data, build and test theories, make new discoveries, and even to communicate with peers. There is hardly an area which has not been impacted in a major way by introduction of ICT. In some cases, science leads in development of ICT applications for a particular purpose.

The major areas in which ICT has impacted and will continue to impact science are:

- Collection, visualization and analysis of data
- Multiple representations of physical qualities
- Simulations for understanding, testing and predicting models, theories and phenomena
- Communication, collaboration in an on-line mode

But rather surprisingly, most of these improvements and advances have not percolated to the teaching of science. We continue to use methods and apparatus which, in some cases, date back to a century! These methods were, perhaps, suited for an era in which more effective tools, such as ICT today, were not available to engage students in learning. However, they are not suited to the learning needs of the present day. We must "upgrade" science education to be at par with science itself. That is to say, science education should consider accommodating current practices in science, especially with regard to ICT, in the learning processes. There are exemplary uses of ICT in science education which have the potential to bring about dramatic changes in learning – processes, as well as outcomes.

Multiple tools are available for use in each of the areas listed above. A good scientist will have many such tools for each category in her/his toolkit. Each tool brings with it a certain set of affordances, and all tools for science may not be suited for science education.

In this article, we will look at these tools with special focus on what they offer to science education. In fact, some of the tools being discussed here were specifically developed for learning.

**Collection, visualization and analysis of data**

Science is built on data. Data is an essential component scientific endeavor. With advances in ICT tools, it has easy to collect data, visualize it and analyze it to fulfill certain objectives. ICT has made it easier to collect and display a large amount of data which would have been very difficult, if not impossible, otherwise. For example, collecting and displaying a few thousand data points in case of transient phenomenon can be performed with a data logger and computer in a few seconds.

We will consider each activity separately.

**Collection of data**

We can see two major ways in which collection of data can be enhanced by use of ICT. They are as follows.

- Collection of real world data (i.e. data collected from real world settings). A variety of data collection devices are available which make collection and storage of data easy. The smartphone itself has many sensors which allows for easy collection of data. Devices like Arduino allow data collection by connecting them to various sensors. Data collection with these devices is very useful for conducting experiments. Electronic collection of data is particularly suited for experiments that require a substantial number of data points or if the data must be collected over a long period (a few hours or days) or a short (milliseconds) time spans.
- Online Data Repositories The data recorded from various institutions and projects are available in many open data repositories. This data can be used to aid the work of students. Because the data has been collected over extended periods, as well as for several periods, it is possible to study long-term trends.

**Visualisation and analysis of data**

The ability to create graphs with data and interpret them is one of the essential skills required for doing science. To make students learn and appreciate this skill, a range of data visualization tools are available. These allow students to 'see' data and 'play' with it, looking for patterns and trends. The visualization tools also aid students to become familiar with many ways of representing data. The immediate feedback that the students get when changing scales or data has shown to increase the contextual understanding of graphs in students. Computerised plotting of data also opens up time for more reflective and analytical questions about the graphs and situations they represent.

Data analysis is perhaps one of the pillars of doing science. ICT tools have allowed us to make sense of the substantial amounts of data that are gathered. In science education, these tools allow learners to look for patterns in data. A simple plotting application with appropriate scales can help learners identify patterns and analyze them. This can lead to forming and testing of hypothesis. They can also aid in modeling of the phenomena by developing equations and fitting data to them.

**Simulation of phenomena**

Simulation of natural phenomena is a very useful way of understanding them. Scientists regularly use simulations to study various natural events and understand the factors that influence them. Simulations help to understand how various parameters affect the phenomena as well as their intensity. They allows us to perform thought experiments, predict outcomes and verify the results.

From the perspective of learning, simulations can be useful at three levels:

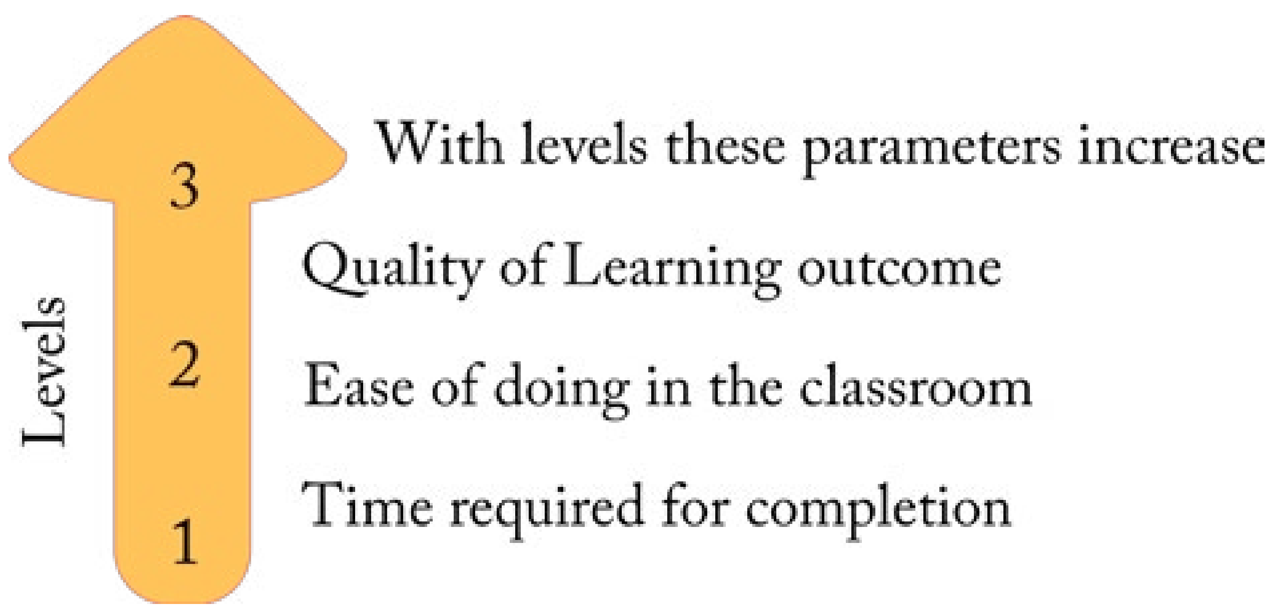
1. The first, or the most basic level is when simulations are presented to the class.The presentation mode is a passive one in which the learners can only *see* the things the teacher presents to them. Even at this level, a set of properly framed questions can set the students thinking.
2. The second level of use is when the learners operate the simulations. This enhances their engagement. They can be guided to do many thought experiments and check the results of some which might be quite unexpected and a moment of discovery for the students. The discussions on the results can lead to interesting perspectives and conclusions.
3. The third level of use is when the learners create the models themselves. There are many applications designed for doing this, such as Turtle Blocks, Scratch, netLOGO. They are some of the best designed software for learning. Building of models allows students to learn from their mistakes (debugging), which allows them to expand the cognitive tools available to them. This is in consonance with Papert's vision (quoted at the beginning of the article). Model-building aids learners to gain an enhanced understanding of the model and the interactions of its several variables. The students work like scientists, exploring a phenomena and trying to understand how it works.

We can see trends in the usage of all the three levels.

• Ease of doing in the classroom: Increases from Level 1 to 3.

• Time required for simulation: Increases from Level 1 to 3.

• Quality of learning outcome: Increases from Level 1 to 3.



**Communication and Assessments**

Rapid penetration of internet and mobile computing has lead to an explosion in communications. This has made it possible to obtain instant responses to queries and store them. Participation in various online fora has led students and teachers to become more communicative. There is immense potential for interactions with experts.

**Peer and Self learning**

The online forums and interactions open a different environment for peer and self-learning. Students can give their feedback and ask questions about each other's work, resolve doubts and answer queries. Data is usually saved from such interactions which facilitates easy access and retrieval. Additionally, they serve as a rich source of information for others.

**Assessment**

Besides its common use to administer (online and offline) tests with multiple choice questions (MCQs) and evaluate performance in them, there are other innovative ways to use ICT for assessments. One of them is ocussed discussions in online forums. Learners' participation can be evaluated for both quality and quantity of responses. The forums can generate analytics for the number of responses by participants. The responses can also be studied qualitatively for their content. In such fora, learners can also get immediate feedback from mentors and peers. This approach is in line with constructionist view that *building of knowledge structures* happens especially aptly in a context where the learner is consciously engaged in constructing a public entity, in this case the comments and responses on the forum.

**OER Resources**

The wide availability of Open Education Resources (OER) has positively impacted learning across the world. We now have access to lectures and notes from domain experts that are available to anyone. This has also made asynchronous learning possible.

The learning resources include (but are not limited to) video lectures , lecture notes , media files like photographs, illustrations, audio recordings, animated gifs, books , and interactive simulations.

**Reflections**

In this brief article, we have seen ways and means by which we can enhance science learning. Each tool/ application provides us with a set of abilities which can create rich and meaningful learning experiences. But we must also realize everything cannot – and should not – be taught through computers. However, there are many areas of science education in which the appropriate use of ICT greatly improves the learning outcomes. In such areas, perhaps, ICT may become indispensable to teaching.

We close with another quote from Papert, which points us to the way we should use ICT in learning:

In many schools today, the phrase "computer-aided instruction" means making the computer teach the child. One might say the *computer is being used to program* the child. In my vision, *the child programs the computer* and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building.

**Credits / Attribution**

"Science Education in the Information and Communication Technology Era" by Amit Dhakulkar for Tata Institute for Social Sciences as given.

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# Unit 03: Principles and Practice of Science Education

# Session 04: Project Based Learning: An example of innovation

## 5 BCase study of designing and making a playground model

***-Saurav Shome***

Chitra sat staring at the diary open in front of her. It was an old diary she had been maintaining all her teaching life. It was all so confusing. Over the last five years, she had attended more than a dozen teacher professional development (TPD) workshops aimed at increasing the awareness of "new and innovative practices" among teachers. A teacher from an eastern Indian state, she had been constantly bombarded with high-sounding words about classroom pedagogy. Teachers were under pressure due to the sustained expectations from them to do something "innovative" in the classroom. Just last week, she too had been told what was expected from her.

"There is a mismatch between the pedagogic expectations from teachers and the kind of challenges I face everyday," she muttered. "And these challenges are not just classroom realities but also

managerial and administrative ones."

Chitra purposefully picked up her pen and started to write. "I will map the teaching realities, pedagogic expectations, and the standards I have set for myself," said Chitra. "That should help me meet

mychallenges."

**Here is the table Chitra created in her diary.**

| Expectations shared in TPD programs | Expectations from district and block functionaries | Expectation I have set for myself | Challenges I face |
|---|---|---|---|
| a) teaching must be thematic, and subject integrated,<br>b) students must learn while engaging in activity based learning, project work, or making and doing something. | a) carrying out detailed and multi-modal assessment, and CCE<br>b) maintain teacher diary and students' box file,<br>c) fill LINDICS and PINDICS on regular basis, and<br>d) conducting "Baal Sodh Mela", "Sapno ka Udan", "Science mela", "Science project exhibition", "Project exhibition," etc. at cluster level every year. | a) enhancing students' reading-writing skill,<br>b) developing students' conceptual clarity in concerned subject area,<br>c) enhancing ability to estimate, visualise, represent, measure, and<br>d) enhance ability to work in group. | a) sometimes students do not take interest in the study,<br>b) it is difficult to teach some concepts,<br>c) students fail to apply learned concepts in novel context,<br>d) regular copy checking is tiresome activity,<br>e) new assessment format seems foreign and irrelevant,<br>f) frequent tests demand more time and do not help filling the new formats of LINDICS and PINDICS,<br>g) no clue on how to maintain box file, and<br>h) students leaing from the existing projects are poor. |

**Journal Notes**

What is your experience of attending workshops and sessions on teacher professional development? What vocabulary of classroom pedagogy you have encountered in such gatherings? Do you think these vocabularies confuses your plan of teaching or teaching itself? What expectations you have encountered in teacher professional development programs that you have attended? Do you have similar challenges? If you are also facing similar challenges, how do you address these challenges? Do you have any suggestions to Chitra? What kind of different expectations do you have from district and block functionaries on you? How do you address these expectations? Do you think that she has kept her standard of expectations quite low? Is she limiting herself to only a few school subjects? What are your expectations, that you have set for yourself? Do all of your colleagues have identical expectations? Is it necessary to have identical expectations? Should all teachers have a set of common minimum expectations? From where these expectations are derived?You can prepare a consolidated list just like Chitra has and share your experience with your colleagues.

**Searching for a solution: Designing project based learning**

Chitra read her notes again. “Umm...how can I teach math and science using activities in Class VI??” She thought. “First, I will browse through the Class VI math and science NCERT textbooks, then I will make a teaching plan and see where and how I can add activities.” She decided.

Deciding content and learning goals: She had first browsed the mathematics and science textbooks of NCERT Class VI. She was also thinking of making the unit interesting for students. “Could I use a project to teach some of the units together?” She thought. The project could be carried out for several days so that some of the contents of these two textbooks can be addressed.

The next day, she heard through her Headmaster that the Panchayat and local members had expressed interest in preparing the school ground as a park-cum-playground for young children between 3 – 7 years of age. “This is an excellent context for the project”, thought Chitra and decided to design a project on making model play items for the proposed park. That evening, Chitra wrote down in her diary a list of concepts from mathematics which included basic geometrical ideas, understanding shapes, fractions, decimals, data handling and data representation, mensuration, algebra, ratio and proportion, symmetry, and practical geometry. Similarly, she also browsed the science textbook and listed the content and concepts. A glimpse of her work is given in Table 2.

| Name of chapter | Name of content/ concepts |
|---|---|
| Fibre and fabric | Fibres are thinner strands that form yarn, There are various kinds of fibres, Different fibres behave differently |
| Sorting materials into groups | Objects around us, There are multiplicity of objects around us and objects can be classified in more than one category, exploring objects & identifying materials they are made of, an object could be made of one or more material, exploring objects that are made of same kind of material, one material can make more than one object, properties of material, different materials have different sets of properties, certain material behave in a certain way |
| Motion and measurement of distance | Measurement of length of straight line, standard units of measurement, |
| errors in length measurement, measurement of length of curved path | |
| Changes around us | Reversible and irreversible changes, some changes can be reversible and some irreversible, change could happen in various ways like change in shape, amount, nature, and properties |
| Body movements | Different kinds of body movements of human |

Table 2: Content and concepts listed from Science textbook

Now, Chitra has listed a big basket of learning goals. It is not possible to accommodate all the learning goals in one teaching plan or in one project. "I obviously can't deal with all of these," she sighed. "Umm, let's see, which core concepts should I pick."

Pleased with the progress she had made, Chitra put down her pen and read her notes all over again. "But wait a minute, this is all very well, but what skills do expect the students to develop after completing the project?" Chitra asked herself worriedly.

| |
|---|
| List of skills:<br>(a) visualisation, (b) estimation of sizes, lengths and areas, (c) measurement skills, (d) making judgements about material choice, their quantities and manipulating (cutting, joining) them, (e) higher order thinking skills of analysis, planning and selection based on suitable criteria, (f) ability to engage in negotiation,<br>collaboration and brainstorming within teams and with the teacher, (g) reading, writing, and comprehension, (h) presentation, and communication. |

Table 3: List of skills prepared by Chitra to address while carrying out the project

"Next week, I will discuss the project with my colleagues and finalise my teaching plan," Chitra resolved.

The next few days, Chitra went around talking to her friends at school. But she was so tied down with completing her syllabus and her administrative tasks, that she was too tired in the evening to work on her plan.

"Ah! Saturday, at last!, Chitra told her friend after the school bell rang on Friday evening. "I will finish writing my plan this weekend."

After several hours of work, Chitra finished writing her plan in her diary. Let's go through her plan.

Teaching Plan on project-based learning

Duration of teaching unit: 24 hours of transaction over 12 days and one additional day for exhibition.

Project title: Designing and making play items for park.

Problem statement: "Panchayat and local committee wished to prepare a park / playground in our school compound. The park cum play ground should be primarily usable for children of age 3 to 7 years. Now you (the students) need to prepare design of play items and make model of these play items."

Preparation before transacting the plan:

1. Communicate ideas to colleagues and head master and explain that the project work would be carried out with students and on the final day they would present their work to the larger audience.
2. Request the head master to communicate this idea to cluster and block functionaries, parents, and members of Panchayat, and local community.
3. Prepare budget for the events on the final day of presentation.
4. Sort out materials like used straw, rope, small wooden sticks, broom sticks, bicycle spokes, news paper, used paper etc., from the repository of discarded and used materials, that the school had maintained for the last one year.
5. Write a detailed teaching plan and regularly revise the ideas, including a day wise material requirement list. As the school do not have large fund, make a day-wise list of materials and source them on a daily basis. For example, borrow two tailors measuring tape on the morning of first day and return after completing the work on the same day; take mug from School Canteen.
6. Purchase a rim of A4 sheet paper, graph papers, pencils, pencil sharpener, pen, cello tape, thread, 2 measuring scale of 30 cm long, some scissors, cutters, and sewing needles etc.

Chitra shut her diary, confident that her plan would work and she would be doing something innovative in her class. There were a few days for the project to begin and she decided to enjoy the rest of her weekend.

**Journal Notes:**

What are the advantages and disadvantages of bringing more than one subject and content area while conducting project? What is your experience in this area?

Have you undergone a similar situation in your teaching profession? You can share your experience with your colleagues.

Do you think, without such context she would not be able to begin the project? What would be other triggers to begin a project?

**Two weeks later…**

Chitra's school organised the exhibition and students presented their work. All visitors appreciated the work of students. Chitra used to go through all the productions of the students each day and make short notes. This helped her to design specific intervention with the particular group or individual students. She also used to walk around and talk to the students while students were doing their work. Chitra took notes for the entire session. Her teaching plan, notes on her plan, along with her daily notes formed a part of teacher diary.

Every team maintained a portfolio of all their productions. And this consisted of the following:

1. Personal information sheet,
2. Write up on measurement of ground,
3. Map of the ground,
4. A bar graph of the data measured,
5. List of 10 playground items,
6. Short list of 5 favourite items,
7. Design exploration,
8. Exposure to technical drawing,
9. Technical drawing of the play items,
10. List of materials,
11. Plan of action,
12. Write up on product, and
13. Self and peer evaluation sheet.

In addition to that several sheets of Chitra's comments on the productions were also attached. All these formed box file for the groups. However, individual student's box file was not prepared from this engagement.

At the end of the project, Chitra had this table with her notes on how the project progressed day by day. Examine the details in the table and make notes in your journal.

**Chitra's Project Notes**

| **DAY 1** | |
|---|---|
| Description | 1)Introducing the project activity<br>2) Measuring playground with non-standard unit |
| Plan | 1)Prepare 10 copies of Schedule, and note on problem statement and expectation from students.<br>2) Arrange materials like<br>a) Rope<br>b) A4 Sheet paper<br>c) Chalk<br>d) Box file for students<br>e) Pencil<br>f) Pencil sharpener |
| Activity | Students formed groups of 3 and named their group. Students' personal information sheet in a consolidated format was distributed to each group.<br>(Refer Box 1)<br>Each group had to keep all their work in the file and maintain it regularly.<br>Problem statement was introduced to students.<br>A copy of expectations from the students was shared.<br>The first task in the activity: Measuring the school compound introduced. Question: How will you go about measuring the playground?<br>After discussing it was decided to:<br>1.prepare a sketch of the ground and measure the sides of the ground using ropes,<br>2. find out the length in standard units, and<br>3. prepare an outline map of the ground. |

| | |
|---|---|
| My Observations | Students' responses included using measuring tape, foot-ruler, by counting our steps, measuring the length of a (wood) log first and using it as a unit, using a "big thin wire". One student, Esmaile suggested measuring the length, breadth, and then area of the ground.<br><br>The measure of all the sides of the ground were not the same, therefore, rope for measuring all the four sides. Different groups came up with different strategies. Chitra reviewed their strategy and resources required. |
| Journal Notes | Could you anticipate some of the strategies evolved by the students? What resources would be required for that? Do you think these resources would be available in your school? |
| **Day 2** | |
| Description | Measuring the length |
| Plan | 1)Arranging all the scales and measuring tapes<br>2) Arranging different strategies to do indirect measurements in standard unit |
| Activity | Chitra had one long measuring tape (20 m), one small measuring tape (3 m), one 1 meter scale, and five 30 cm scales. She used all these scales in multiple ways so that all the groups could measure the length of their ropes at the same time. And each group had to undergo all these ways. Students had to note down the length of the ropes in standard unit in a table. (Refer Box 2) |
| My Observations | None of the students paid any attention to zero errors while measuring. They were not very careful to maintain correspondence between sketch and the actual track they had measured. The students also made some mistakes while adopting a particular strategy due to carelessness, and that was minimised while repeating the same. From the table it was observed that the measure of length varied according to individuals and groups. Chitra discussed different relationships used in the measurement strategies she had designed and the students actually carried out. Some of the methods designed by Chitra were not grasped by the students. |
| Journal Notes | According to you, what are the different measurement modes Chitra could have designed? |

| **Day 3** | |
|---|---|
| Description | Plotting graph from data and preparing map of the ground |
| Plan | Arrange materials like:<br>(a) Graph paper<br>(b) Additional pencils and sharpeners<br>(c) Measuring scale<br>(d) A4 size paper |
| Activity | Students plotted bar graphs of the data presented in the table. Each group prepared a map of the ground on a A4 sheet paper. Chitra introduced the idea that a scale had to be decided to make a map on the paper as well as the model of the items to be made. |
| Journal Notes | According to you, what kind of discussion could have been initiated in her classroom? Do you think, Chitra could have resist her temptation to enter in some area like making a map of the ground, that was not included in her plan? Was this task worthwhile for the students? |
| My Observations | Students had lots of difficulties making graph and preparing a map of the ground.<br><br>For the scale, one student, Ramesh suggested a scaling down to ¼ while Kiran calculated that the scaled length would be more than the length of the classroom! Ruchi suggested a 1/6 scale and Jeenat followed that with 1/10. |
| Journal Notes | Chitra was aware that the data collected by students were not error free. Still she had asked the students to plot bar graph. What pedagogic purpose did it serve? If you would encounter the identical situation what would be your pedagogic response? |
| **Day 4** | |
| Description | 1)Making list of 10 playground items<br>2) Making short list of 5 favourite items |
| Plan | 1)Arrange materials like:<br>a) A4 Paper<br>b) Additional pencils and sharpeners<br>2) Photographs and videos of Indian parks showing several play items installed in the park |

| | |
|---|---|
| Activity | In this session, students were asked to note down 10 play items to install in the playground. Once, the students listed 10 play items, they were asked to select five play items, give sketches of each, and justification for putting them in the playground. They had to fill a worksheet provided to them. Students were also shown pictures of playground items and videos of a few innovative low-budget playgrounds in Indian school setting. |
| My Observations | It was pointed out that the items had to be ones on which children could play. This aspect did not become clear to the students, as items like flower bed, bench/seat, fountain and pond were included even in the final list of some groups. One group thought that each group would be designing all the items and the entire playground. Ruchi raised safety issues after watching merry go round video saying that very young children couldn't play. |
| Journal notes | Do you find any reason for the students to include non-play items? Do you think, the exercise of choosing 5 play items out of 10 items was required? What kind of purpose does it serve for students learning? |
| **Day 5** | |
| Description | 1)Selecting a play item to design and make in groups<br>2) Design Exploration and scaling discussion |
| Plan | 1)Arrange materials like:<br>a) A4 Paper<br>b) additional pencils and sharpeners<br>c) measuring tape |
| Activity | I have prepared a list of ten most common play items. Now, each group had to work on designing and making any one play item.Before that they had to explore the design of their chosen play items.<br><br>All the groups decided the scaling factor of their play item and model playground. The discussion arouse interesting learning opportunities.<br><br>For example, every group had to estimate the dimensions of the play items taking into consideration of the height of children of 3 to 7 years old. I encouraged students to estimate lengths, instead of wildly guessing and suggested that they can compare length with their own body sizes. So several students, who did not know their own heights, for instance, started measuring their heights |

| | |
|---|---|
| My Observations | One student was good at estimating height of the room as 3.5 m but was poor with estimating small sizes like a few centimeter. Two students had trouble estimating lengths altogether. In fact all students struggled with estimating real sizes of items in the playground. But with a little help and measuring their own sizes, and estimating sizes of younger children, they arrived at close estimates.<br><br>This estimation task also brought in discussion on change in unit and proportional reasoning. One way to exchange the unit was using measuring scale having marks in both units. A similar encounter of situation that elicit understanding of proportional reasoning would be possible in model making task. |
| Journal Notes | What are the ways in which we can teach students to estimate dimensions? One example is using body parts. Finger segment of a middle school child is close to one centimeter. |
| Activity | Students explored the possibilities of making their play item by drawing. It was an attempt to represent the actual model on paper. Each group made more than one design drawings. They had also made separate design drawing of the specific part of the play items that they considered complex to work on or explain to their friends. Design exploration made by one the group is shown in Figure 2. |
| My Observations | Three of the groups tried to show outline of the item model as others tried to show minute details of the model. Some of them were successful in sketching 3D objects on 2D paper using cylindrical structures (see Figure 1). But initially all of them found it very hard to imagine and to capture the model on a plane paper. |
| Journal Notes | Do you think integrating science and mathematics is a good idea? Has it ever happened that you used a concept from geometry or algebra in science class? Did you explained it there or relied on students' knowledge? Did you ever thought of collaborating with the fellow maths teacher?According to you, what is the justification of including design drawing before making task? |
| **Day 6** | |
| Description | 1) Exposure to technical drawings - Drawing a mug<br>2) Completing design drawing, technical drawing,<br>3) Listing / quantity of materials and tools |

| **Day 7** | |
|---|---|
| Description | 1)Learning to plan: making a firki<br>2)Planning item model making and work distribution<br>3) Presentation of the model design and work plan |
| Plan | Arrange materials like:<br>(a) used papers<br>(b) A 4 paper<br>(c) additional pencils and sharp eners<br>(d) 10-15 board pins<br>(e) some kind of soft stick (so that board pin can be inserted) to hold the firki<br>(f) small pieces of straw |
| Activity | I have handed over the instruction sheet (Refer Box 3) to all the students. The instructions were also accompanied by visuals. Each group was asked to prepare a detailed plan of work and work distribution. And this plan need to be presented before other group on the last period.Students presented their plan in a table. (Refer Table 4) |
| My Observations | All the teams read the plan of action of making firki and found it easier to create one. Making of a firki gave them a sense of what exactly they have to do, who would do it and in what way, in making of their model. In presentation students mostly discussed on the fixation and safety issues. In a few cases some of the confusions of presenters were resolved after getting others'input.The'Three Champion' group was not ready to talk about work distribution so they were busy with their work. I had to ensure that entire group was involved in presentation |
| Journal Notes | Do you think art and craft can provide useful inputs for science? Do you think science plays a role in art and craft? Read about STEAM and write your reflection. |
| **Day 8 & 9** | |
| Description | Making of item model |
| Plan | Arrange all the materials listed on Day 6 or their alternatives |
| Activity | I made the material available to students and groups were asked to prepare models of the items. |

| | |
|---|---|
| My Observations | Observed that there is not much progress in the 'Three Champion' group. Finally, their model appeared different from their sketch of the model.All the groups did a "good teamwork" in making of the play item. The members listened to each other, shared their group work without conflict, they had anticipated the problem and each others challenges, and worked for completing the goal. |
| Journal Notes | What kind of challenges might appear while doing this making task? Do you think, similar kind of problems would appear in your classroom too? What will you do to address these challenges? |
| **Day 10** | |
| Description | Evaluation of the play items |
| Plan | A clear format of evaluation sheets in print (both individual and group evaluation). |
| Activity | I handed over a copy of evaluation sheet to each group. A copy of the format is given in Box 4. Now I spread out all the play item models in such a way that each group can go to a play item and evaluate the model. |
| My Observations | While students were evaluating each other's play item model, I was hearing the conversation of the students. This discussion also gave a rich source of students understanding to me. In some cases, I posed some questions to the groups. It was decided that next day all groups will write a report with a proposal to install these play items in the ground. |
| Journal Notes | Have you ever used peer evaluation in your classroom? Do you think it is possible? Do you think students learn from evaluating each other's work? |
| **Day 11 & 12** | |
| Description | 1.Preparation of the report and letter to Panchayat pradhan<br>2. Preparation for the exhibition |
| Plan | Reading of all the box file carefully and preparing an outline of the report. |

| | |
|---|---|
| Plan | Arrange materials like:<br>(a) One or two mugs,<br>(b) A 4 paper,<br>(c) additional pencils and sharpeners |
| Activity | I made a technical drawing of a mug (as anexample). Told the students that representing shape and size were most important in case of technical drawing. Size could be shown with the help of leaders and arrows, dot and dash line to show axis, dotted line to show hollowness, cross to show centre. Each team thoroughly looked at their technical drawing (See Figure 3) and made a list of materials. I told them to mention length, breadth, height, inner diameter and outer diameter of all materials required. |
| My Observations | Making technical drawing created a context for students to find out geometrical properties. For example, students drew a circle on paper and started searching for longest chord by placing ruler at different points. In that process they realised that the intersection of any two diameters could give centre of the circle. But they had to face one more question which was length of all the diameters were of same size or not. They were shown how to get to the centre of circle by paper folding method. Then they took the measurement of two diameters and concluded that all diameters have same length. The students found it difficult to make a technical drawing of a mug even after the exposure. The most difficult aspect was deciding the views. Also idea of inner diameter and outer diameter were discussed. They always drew perspectives rather that top and side views. Overall, students seemed reluctant to draw top views, choosing instead a mixture of side and top views. This was especially true for the mug, which has circular cross section.<br><br>Another difficulty was deciding where to use dashed or solid lines, like difficulties drawing leaders, arrows and then write dimensions and units. They draw arrows without leaders and write dimensions outside the arrows line, and so on. These examples can be seen throughout the mug and also in their attempts at drawing the technical drawing of their item models.<br><br>Some of the lists were partially complete. Students had to redo some work to give dimensions of the materials that they need. The estimated amount of materials students listed are often over or<br>understated. |

| | |
|---|---|
| Activity | Each group wrote a detailed description of each item model and how these models could be used in the actual ground after adequate modifications. Students also commented on some other but relevant aspects like (a) what modifications need to be made in the item model before making actual play item, (b) what care must be taken while making this items, (c) students of which age group would have access to certain kind of play items, (d) what safety issues are associated with the use of these play items. In addition to that students prepared a budget to implement this idea. To prepare budget, students had to know the material to be used for the play item, amount of material required, and price rate of each material. |
| My Observations | Through this project several of the learning objectives has been achieved, however, some of them were not. |
| Journal Notes | According to you what learning objectives has been met and what remained?<br>What suggestions you would like to give her for improvements? |

***Figures***

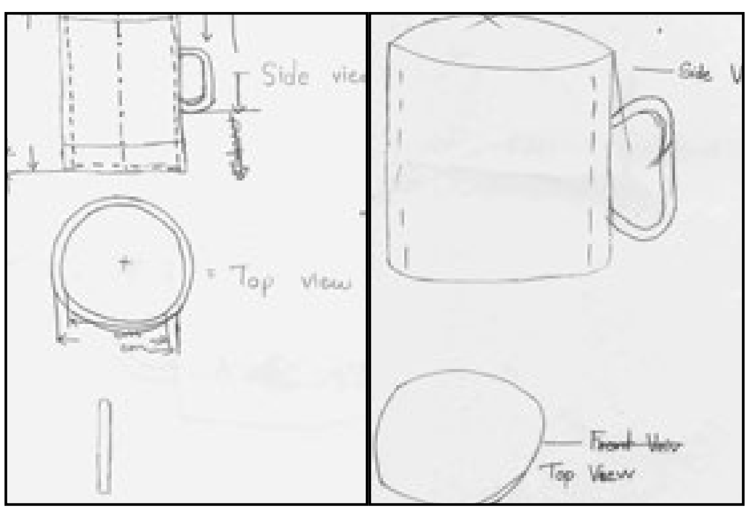


***Figure 1:*** *The technical drawing of a mug prepared by one group 'Three Champions'*

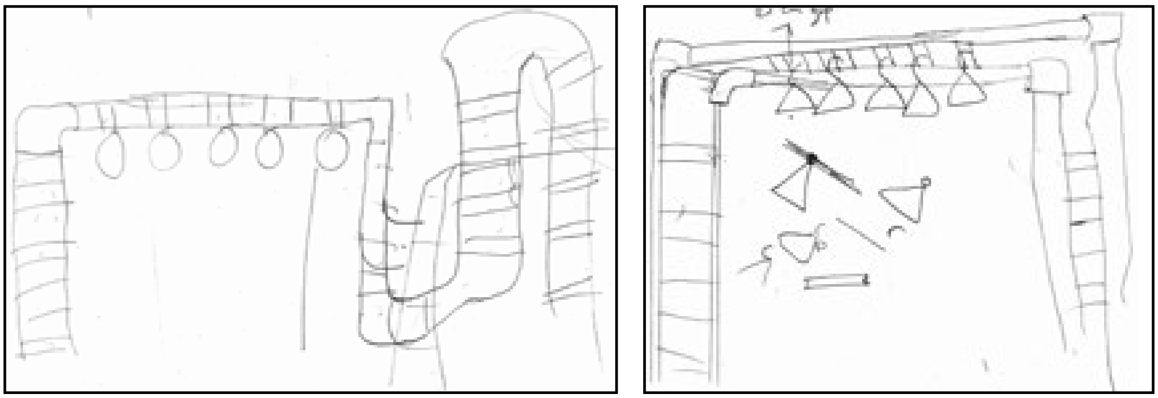

***Figure 2:*** *Design explorations made by Three Champions*

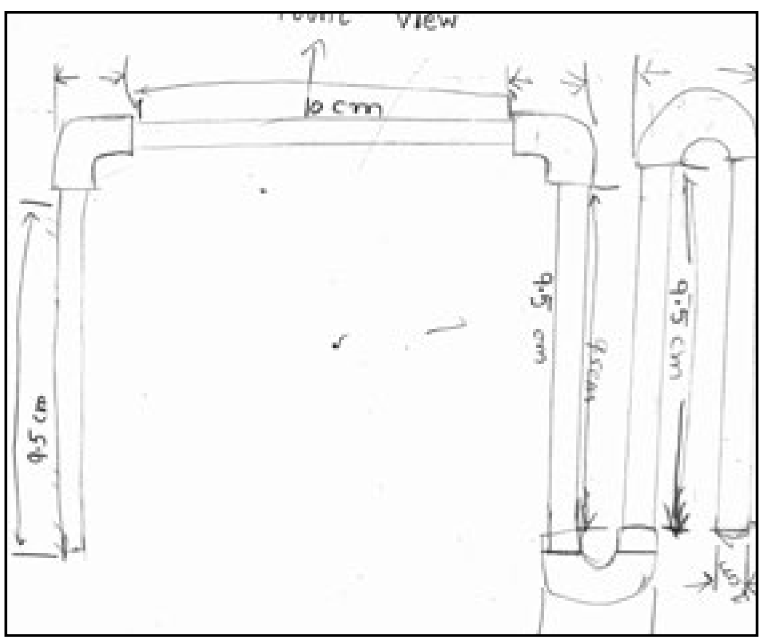


**Figure 3:** *Technical drawing prepared by Three Champions*

**Supplementary Material**

| Name of Group:<br>About you: | | | |
|---|---|---|---|
| Name of group members | Subject you like most | Things you are very good at | Your hobbies |
| | | | |
| | | | |
| | | | |

***Box 1:*** *Format of personal information of group members (Referred in Activity Plan of Day 1)*

| Name of group | Name of the members measured the length | Length of side 1 (in m) | Length of side 2 (in m) | Length of side 3 (in m) | Length of side 4 (in m) |
|---|---|---|---|---|---|
| Group 1 | Rosemary | | | | |
| | Arindam | | | | |

***Box 2:*** *Referred in Activity Plan of Day 2*

**Instruction sheet for Make firki Yourself!**
You can make a firki on your own, following the following instructions

1. Mark on the paper 14 cm ( from left hand side bottom corner) on the left side and 14 cm on the bottom. Join both the points with a straight line.
2. Fold the paper on that line and draw (vertical and horizontal) lines with the help of the folded corner.
3. You will see a square when you unfold the paper to its original position. Cut the squares with a pair of scissors.
4. Draw a line joining intersecting the earlier drawn line. Put a mark on the lines 2 cm from an intersection. Put a mark on the right side of both the hypotenuses. If you want, you can decorate with some drawings.
5. Cut from the end of a square to the 2 cm mark.
6. Join the corner of the cut square on the intersection and fold.
7. Do the same for other corner as well.
8. Pin up the four corners of the square (on the intersection) with the help of pin.
9. Place pencil or eraser on the pointed end of the pin so that you don't get hurt.
10. You can change the size of firki. However, small firkis work better than larger ones.
11. When you blow air on the blades of firki, firki will move clockwise. If you want firki to move in anticlockwise direction, put mark on the left side of the corners.

***Box 3:*** *Instruction sheet to make Firki*

| **Evaluatio sheet<br>Evaluator group name:** | | | | | |
|---|---|---|---|---|---|
| Group name | | | | | |
| Item name | | | | | |
| Is model proportionate in dimension? (Yes / No) | | | | | |
| Is model scaled correctly? (Yes / No) | | | | | |
| Use pf material: Suitably used = 3, mostly suitable = 2, not at all suitable = 1 | | | | | |

| Usethefollowingcriteriatoratethemodelsonascaleof1to(5=excellent,3=average,1=unsatisfactory): | | | | | |
|---|---|---|---|---|---|
| Group name | | | | | |
| Item name | | | | | |
| Stable (will not fall eas-ily) | | | | | |
| Sturdy (long lasting) | | | | | |
| Strong (will not break) | | | | | |
| Safe | | | | | |
| Easy to use | | | | | |
| Aesthetic (good look-ing) | | | | | |
| Write about each play item: | | | | | |
| Group and item name | What are the good as-pects in the model? | What are the problems with the model? | How can the model be made better? | | |
| | | | | | |
| Any other comments: | | | | | |

*Box 4: A format of evaluation sheet*

**Credits / Attribution**
"Creating a culture of scientific inquiry in the classroom" by Aisha Kawalkar for Tata Institute for Social Sciences as given.
This article is adapted from an earlier work:
Shome, S., Shastri, V.V., Khunyakari, R. and Natarajan, C. (2011). What do students learn from designing and making a playground model. Proceedings of PATT - 25, pp.357-366.

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# Unit 03: Principles & Practice of Science Education

# Assignment 3: Textbook Analysis

## 6 Reading between the lines

***-Himanshu Srivastava***

We all agree that infrastructure like science labs, digital teaching-learning resources, and sufficient space is essential for imparting quality science education in schools. Adequate class time is important for discussion and inquiry. But the reality is different, as we all know. There is no flexibility in the timetable. A class period of 30-35 minutes does not allow sufficient time for all students in a class of 40 to perform experiments. Combining two periods can help but it is not permitted by the rules. Digital resources that are available to teachers are of inferior quality; they do not enable interactive learning and help students construct knowledge as they learn. Moreover, assessment focuses on how much a student can memorize rather than his/her conceptual understanding, or the ability to apply the knowledge learnt.

More worryingly, in most schools, science labs are dysfunctional or are used infrequently. But, on the positive side, some teachers are using locally available low-cost material to explain and demonstrate concepts in science. If you are also doing such things in your school, your efforts must be commended.

We must accept that there is no ideal method for teaching science in school. But there is agreement among educators that our approach to teaching must consider the contexts in which learning takes place. For this reason, as teachers, we must also accept that there is always scope for improving our understanding of the subject matter and for using methods that are better suited for explaining a given concept. Therefore, teachers must be sensitive to their students' needs and actively involve them in the learning process. They must respect their students' ideas and everyday experiences. The mistakes that they might make is integral to the learning process.

In this article, I would like to introduce an important dimension to which we must pay attention for bringing quality education to our students. I am referring to the textbooks we use to teach. They are central to our education system. Textbooks are a vital learning resource because, as Prof Krishna Kumar of Delhi University put it, they are the *only* resource available in the majority of our schools!

In such a situation, teachers do not have a choice. They cannot select or organize content for their classes. This fact is acknowledged in the position paper on 'Curriculum, Syllabus and Textbooks' of the National Curriculum Framework, 2005, which highlights teachers' dependence on textbooks:

- The textbook has become an '*embodiment of the syllabus*'. Teachers are expected to teach only what is in the textbook and nothing more!
- The textbook is also *the* evaluation system because the students' learning is judged by his/her ability to answer the questions by reproducing appropriate text from the book.

Therefore, it is necessary to subject textbooks to critical review. It is crucial that teachers understand how good their teaching resources are before they use them in their classrooms. After all, as a professional is expected to be accountable for the quality of his/her work, one must critically evaluate one's tools before putting them to effective use.

Eklavya's experience

For the past few years, we at Eklavya have been holding a session on textbook analysis (TBA) in our annual weeklong workshops. These workshops are organized to help the participants enhance their understanding of the subject matter; and understand what it means to do science and how to investigate a question in a science classroom.

The objective of these TBA sessions is to empower participant teachers to develop a critical outlook toward curricula and textbooks. Since teachers are accountable for their students' learning outcomes, they must have a major say in deciding textbook content and how topics should be discussed. After all, they are the ones who teach and help their students make sense of the text. Subject experts, educationists and bureaucrats, who are tasked with bringing out the textbooks, are not burdened by this responsibility.

Teachers know what works best in their respective classrooms. They face their students' questions and address their concerns on an everyday basis. They are also answerable to anxious parents as well as the larger community. If all that is required of them is to convey textbook content and complete the syllabus, which was set by higher officials, their sense of autonomy is lost. Critical engagement with the syllabus and textbooks is one way to bring back that autonomy.

In the TBA sessions, participants study the curriculum documents and assess the textbooks they use critically. They also discuss the thinking and considerations that go into their development. As they brainstorm on these matters, they learn about general as well as subject-specific teaching challenges. As a result, they learn more about the resources they are using on everyday basis. Our experience has been that such reflective exercises contribute substantially to their identities as professionals.

**Textbook Analysis (TBA) Sessions**

In a typical TBA session, participants are divided into groups of 4 or 5. Each group is asked to reflect on two questions:

1. What should be the aims of science education? Justification must be provided with the answers.
2. To achieve these goals, what kind of topics should be included in the middle school science curriculum and how should these topics be dealt with?

The groups are given time to reflect on these questions. Then, a group discussion is held and group responses are compiled on the blackboard. Sometimes their answers need rewording to improve comprehensibility. We have observed that, despite their diverse backgrounds and experiences, the teachers usually cover almost all the crucial aims discussed in any curriculum document. Then, the teachers are given selected readings from the position paper on teaching of science which contains discussion on the six validities that a science curriculum is expected to abide by. This reassures the teachers about the direction of their thinking, which, in effect, formalizes the outcome of the exercise.

We have also operationalized these validities in the form of a few questions that serve as the analytical framework for TBA (Appendix - 1). The process, in brief, is as follows. Participants are assigned chapters from the textbooks for study. They are then required to answer the questions in the analytical framework for TBA.

Toward the end of the session, all the participating groups present their analyses and clarify their positions if required. In the next section, I will describe one such session that took place in the 2013 workshop held in Hoshangabad.

**The 2013 workshop for science teachers**

The TBA session in this workshop was divided into three parts.[1]

In the first part, the participants were given different texts on photosynthesis – one chapter from a Class 7 science textbook of the Madhya Pradesh State Board and chapters from Eklavya'sBal*Vaigyanik* (old and new editions). No analytical framework was provided and they were asked to compare these texts and list down the criteria they employed for analysis.

In the follow-up discussion, the groups presented their analysis as well as the points they had considered while comparing the texts. To a considerable extent, their points were like the ones discussed in the position paper on teaching science. Therefore, for the next exercise, we gave them two more problems to ponder upon in groups before the chapter review exercise. The teachers were asked to suggest appropriate aims for science education and justify their views i.e. explain why they thought those aims were important. They were also asked to suggest ways to meet the aims of science education i.e. what should the desired syllabus be and what kind of textbooks would be required to achieve the suggested aims.

The questions led to lively discussions in all groups. In the follow-up common discussion, the groups shared their views, which were summarized on the blackboard. The participants were then asked to imagine a situation where several people (educationists, policy makers, subject experts, etc.) from diverse backgrounds and having various experience come together to make a policy document that must reflect consensus on various matters related to education, including the political dimension. (A similar exercise was carried out in 2005. It was much more rigorous and the committee, which was given this responsibility, had prepared a comprehensive list of the aims of science education. These were documented in the position paper on teaching science. This fact was shared with the participating teachers.)

1 We have revised our strategy after this year but the broad structure of the workshop remains the same.

The relevant pages from the position paper and the six-validity framework were distributed for reading in small groups. The participants found that, except for the language used, their concerns were like those stated in the document. After a session in which these aims were discussed, they were given textbooks to review. The teachers had to choose one chapter from any middle school science textbook and review it critically. The six-validity framework mentioned in the position paper was converted into sixteen questions (see Appendix- 1), which the teachers had to answer while analysing the chapter.

Later, the groups were asked to present what they discussed in their groups. The purpose here was to see if the whole class could reach a consensus on the issues and how close to (or far from) their aims and methods were in comparison to those mentioned in the NCF document. There was consensus on nurturing the scientific temper among children as an important goal of science education. The participants were also convinced that science education plays a significant role in inculcating values like objectivity, honesty, and scepticism. However, there was less agreement about the universal nature of ethical principles i.e. whether these principles are independent of time and space or contingent upon socio-cultural conditions.

The discussion ended without a conclusion due to time limitations. But some participants could appreciate that while science education does inculcate certain values, these values are not universal and need to be critically examined whenever there is an effort to develop a new science curriculum. A significant omission from the discussion was that none of the participants mentioned the need to transfer the historically accumulated body of knowledge to the younger generation. This point was, in fact, added by one of the resource group members.

To justify the aims of science educations as articulated by them, the groups expressed their belief that these were necessary in order to bring about positive changes in society and help people to not only develop livelihood skills, but also develop their capacities for continuous learning and actively contribute to the construction of knowledge.

On the syllabus front, there were suggestions from various groups which included, among others, involving the students in conducting investigatory projects, organizing field trips, conducting case studies and interviews, encouraging classroom discussions on controversial socio-scientific issues and letting children find solutions to real-life problems instead of providing readymade answers. Almost all participants saw a science teacher (or, a teacher, in general) in the role of a facilitator. There was also near unanimity in the view that the language used in the textbooks and classroom transactions should be simple, unambiguous and comprehensible to learners.

Finally, the groups presented the analysis of their respective chapters.

Summary of the reports submitted by different groups:

| | | |
|---|---|---|
| Group 1: | *Objects around us* | (Class 6 science textbook followed in state ‘X’) |
| Group 2: | *Useful plants and animals* | (Class 7 science textbook followed in state ‘X’) |
| Group 3: | *Man-made objects* | (Class 8 science textbook followed in state ‘X’) |

| | | |
|---|---|---|
| Group 4: | *Measurement* | (Class 6 science textbook followed in state 'Y') |
| Group 5: | *Gravitation* | (Class 9 science textbook followed in state 'Y') |
| Group 6: | *Reflection of light* | (Class 7 science textbook followed in state 'Y') |
| Group 7: | Light | (Class 7 science textbook followed in state 'Z') |

Each group presented a detailed report. The reports are available with Eklavya and are summarized here.

**State X:** In the textbooks used in the State 'X', it was found that the content and language was appropriate for the level they are used in. In respect of technical correctness of the content, only one group pointed out that the relative spaces shown between molecules of solids, liquids and gases were not appropriate. However, all groups had reservations on the clarity of pictures and images as well as appropriate use of terminology. One group also pointed out that the relative sizes of rats, fleas or elephants were not shown in the correct proportions in the drawings. It was also observed that there was hardly any mention of – or suggestions for – activities in the textbooks. The participants felt that the textbooks did not provide the encouragement to students for questioning or sharing relevant experiences from their everyday lives. The group also noticed that, despite there being scope for discussing social and environmental concerns, the chapters omitted these aspects. In Useful plants and animals, the authors had adopted a purely anthropocentric viewpoint. We agreed that this is neither appropriate nor convenient in the present day and that a broader ecological framework must be considered while designing textbook content.

**State Y:** Textbooks used in the State 'Y', had similar issues. The group, which reviewed the chapter on measurement, pointed out to gender disparity in the diagrams as well as in the narration. The group also highlighted difficult and new words (terms and expressions), which were used without a proper introduction. Apparently, it was presumed that the students were already familiar with such words, which, we know, might not be true. An example is the expression 'physical quantities'. Since the chapter on measurement includes some history about the topic, it was suggested by the group that the authors of the textbook could have discussed the use of various units of measurement that were used in the past. They could have also explained the rationale for keeping the standard 1-metre bar in an office at France, and so on. In the chapter on gravitation, no experiments were described and, most significantly, the difference between mass and weight was not explained.

**State Z:** In the science textbook of State 'Z', it was reported that the introduction to natural and artificial sources of light was not clear. The experiment was described without a discussion of its aim. The connection between two experiments to show that light travels in a straight line (the standard card board and the bent pipe experiments) was also not made properly. Questions at the end of the chapter only tested recall capability of the students.

In their presentations, the groups covered almost all the points discussed in the worksheet. However, some internal contradictions were observed in their presentations, which showed that the points should have been discussed in more detail. In one case, the group mentioned that the language of the text was clear but they also commented on the extensive use of new technical words in the same text. Technical incorrect statements in the chapter were seen as a source of misconceptions among students and were not pointed out as mistakes made by authors. It is likely that the teachers were not used to such intense discussions and they needed time and facilitation for small group discussions.

**Broad lessons from TBA sessions**

1. The textbook is just one among many tools that can be used in teaching. It is necessary to look for alternative resources, which can be used in class.
2. Textbooks need to be seen only as suggested resources. At best, it gives the teacher a sense of the content that needs to be covered. Organization of the content must be done based on the learning needs of students.
3. The textbook is not an authoritative source of subject knowledge. It is important to accept that, despite all attempts to make it error-free, the possibility of conceptually incorrect or unclear content remains. Teachers should not unquestioningly rely on textbook content.
4. Diagrams and graphic representations can be incorrect and misleading.
5. The language of a chapter might not be sufficiently clear due to which students may find it difficult to comprehend the text. Rather than compelling the students to memorize difficult words, teachers must explain in simple terms so that students can understand the various concepts and topics.
6. Total adherence to textbook will leave little or no space for inquiry and discussion. It is always advisable to pause and encourage students to critically reflect on the subject matter, ask questions and encourage students to share relevant experiences, if any.
7. The textbook might not adequately represent the socio-cultural context of the students. Teacher
8. may have to explain with appropriate examples to help children to understand.
9. Teachers must be very careful while referring to textbooks in the classroom. They must be alert to values and ideologies that are likely to be communicated, directly or indirectly, while teaching. If values that are against the spirit of our constitution are being promoted or encouraged, such as discrimination of any kind, teachers must exercise their power to regulate the discussion and ensure that the ideals of justice, liberty, fraternity and equality are not lost.

It is difficult to claim that short reflective exercises, such as the one described here, would necessarily lead to empowerment of the teachers who participate in them. In fact, there is no data to suggest such a possibility. However, at Eklavya, we hope that a few teachers, at least, would find such activities useful, and apply the framework to analyse other chapters in the textbooks they teach from. As we continue to organize similar sessions on textbook analyses, we are convinced more and more that there is no shortcut to empowering teachers. Sustained efforts are called for at various levels. But it is important that, as a professional, a teacher must evaluate his/her ‘tools’ critically. The framework suggested in this article may be useful for this purpose. We hope that similar sessions are made a part of national and state-level teacher education programs.

**Further reading**

1. Prof. Krishna Kumar's article - Origins of India's "Textbook culture"
2. NCF Position paper on 'Curriculum, Syllabus and Textbooks'
3. NCF Position paper on 'Teaching Science'

**Assignment questions**

1. What should be the goals of science education? Give arguments to support your position. Choose any chapter from a science textbook and analyse it regarding the points given in Appendix -1. Also, explain how can this chapter be improved?
2. Write a letter to the education minister stating five strengths and five weaknesses of the current science textbooks in your state.

## Appendix – 1

**Points for chapter analysis**

1. Which goals of science education are getting addressed through this chapter? Give justifications for your answer.
2. What seem to be the assumptions about the prior knowledge of students? What makes you say so?
3. What seem to be the assumptions about the socio-economic background of students reading the textbook? Which contexts are getting adequately represented and which are not? What makes you say so?
4. Do you find the chapter appropriate for that class? Please pay attention to the difficulty of the subject matter as well as the language of the chapter.
5. Which concepts have been included in the chapter? Are there other important concepts related to this topic, which are important from the point of view of conceptual understanding but have not been included in the chapter? What could be the criteria for deciding the content?
6. How does the content of the chapter help students learn the concerned topic? Where does the chapter fit in the larger structure of science? Did you notice any technical and/or factual mistakes in the content?
7. Has the topic been developed in a historical way? Does it help students understand the historical evolution of the ideas related to the chapter?
8. Which values are getting promoted through the chapter? What value lessons will students draw from this chapter? Give justification for your answer.
9. What image of science might students construct after reading the chapter?
10. What do you think about the presentation of the chapter in terms of pictures and diagrams?
11. Does the chapter provide students opportunities to engage in hands-on activities? Give examples.
12. What is the weightage given to the chapter in the exam? What kind of questions is asked from this chapter?
13. What is the nature of questions given at the end of the chapter? Will questions make students think and apply their knowledge in different situations, or test students' recall capacity?
14. Pedagogy:
    a) What are the opportunities for students to share their experiences, argue with each other, or evaluate evidence for a claim?
    b) What are the opportunities for students to ask questions or test a scientific claim? Do the text present multiple positions / perspectives on an issue? Or, do they advocate one viewpoint?
    c) Are students encouraged to collect information on relevant issues? Or, must they just memorize the information given in the chapter?

15. Do you feel the need of writing this chapter differently? Why or why not?
16. If you get a chance to change the chapter based on the needs of the students of your school, what changes would you like to make?
    a) Which issues / concepts will be emphasized?
    b) What kind of examples will be included?
    c) What will be the pedagogy?
    d) How will you assess students' learning?

**Credits / Attribution**

"Reading between the lines" by Himanshu Srivastava for Tata Institute for Social Sciences as given.

**About the Author**

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# Unit 4: Objectives of Science Education

## Session 4: Science and Society

## 7 Socio scientific Issues in Science Education

***-AswathyRavindran***

**A classroom scenario**

It is a Monday and an unusually warm afternoon for April. In most classrooms in ABC school, teachers lecture while bored and uninterested students glance at their watches, wondering why the seconds are ticking away so slowly. In class IX A, however, there is a buzz of unusual activity. Hema, the science teacher, and her students are engaged in an animated debate. Hema is discussing the topic of reproductive health with her students. A particular sentence in the textbook that she read out sparks off a discussion.

Teacher (reading out from the textbook): The sexual act always has the potential to lead to pregnancy. Pregnancy will make major demands on the body and the mind of the woman, and if she is not ready for it, her health will be adversely affected. Therefore, many ways have been devised to avoid pregnancy […] Surgery can also be used for removal of unwanted pregnancies.

Mini: Ma'am! By surgery, do they mean abortion?

Teacher: Yes.

Mini: But...but...the other day I was watching a programme on TV where they were discussing abortion ... and a person in the discussion said that it is wrong because life begins before birth... I think I agree with her...

Suraj: They are talking about removal of "unwanted pregnancies" here...

Mini: But the baby still has the right to live!

Teacher: Yes, but what if the mother does not want to raise the baby? These options have to be there, right?

Mini looks unsatisfied and a little upset. Another girl, Susan, speaks up.

Susan: I think I agree with Mini, Ma'am. The baby, even if inside the womb, is living. So abortion would amount to murder.

Deepa: We cannot call an unborn baby living!

Teacher: Well, so when does the baby start living? Before it is born or after?

The otherwise dull classroom suddenly comes alive. The teacher points to a group of three boys engaged in serious discussion.

Teacher: You three over there! Can you please share with us what you are discussing?

Arif, one of the boys, stands up.

Arif: Ma'am, I think a baby starts living as soon as it is a zygote.

Teacher: Interesting! But what makes you say that?

Arif: It has the ability to multiply!

Neha : Yes, ma'am, he is right!

Teacher: Well, agreed. But now, let's put it this way – how does it become wrong to remove a mass of cells that can multiply?

Annie: I don't think it is wrong to kill a mass of cells because they can multiply. If we extend that logic, then it should be wrong to remove cancer cells!

Teacher: Do people agree with Annie?

Arushi, a lanky girl sitting in a corner of the classroom, stands up.

Arushi: Ma'am! I think it is wrong to kill anything that feels pain.

Teacher: It is wrong to kill anything that feels pain. Would everyone agree with that?

There is silence in the classroom. After a few seconds, Suraj speaks up.

Suraj: I agree! ... I think once we know if the mass of cells feel pain, then we can decide whether abortion is right or wrong.

Sachin: I really don't understand why we are so bothered about whether a mass of cells can feel pain or not. We should be worried about the parents ... the mother! ... What if she cannot take care of the child!

Arushi: Yeah, I think Sachin has a point ... What if the child is born with some disability or something ... the parents may not want to raise such a child.

Susan: I disagree! Whatever be the condition of the child, she is a gift of god and we have to accept her as she is.

The discussion goes on for the entire class period.

**Socio scientific Issues**

Socio scientific issues lie at the interface of science, technology and society and are controversial in nature, as people find it difficult to come to a consensus on what is right and what is wrong — or ethical concerns — in these issues. In the scenario presented above, the issue of abortion that the teacher and the students debated is a socio scientific issue.

Of course, most people reading this scenario would say that such classroom discussions are a work of fiction (which happens to be the case here) and rarely occur in our classrooms, science classrooms in particular. Why is this so? One reason, of course, is student participation. The fictional scenario has quite a few students raising questions and challenging the teacher, which rarely happens in real classrooms. Second, very often, students are ill-equipped to think through such controversial issues. Third, the discussion is actually occurring in a science classroom, where such controversial issues are never discussed.

The important question, however, is not whether discussions on socio scientific issues normally happen in science classrooms, but whether it is desirable to have them at all in the science syllabus. There are no easy answers to this question, and educationists are divided on the matter. One group of educationists believe that science teachers ought not to be concerned with teaching socio scientific issues, which are better left to language or social science teachers. Another group believes that such issues ought to be given a prominent place in the science curriculum. Take a moment to think of your opinion on this point.

In my opinion, the answer to the question of whether socio scientific issues should be a part of the science curriculum depends on our vision for science education, what we wish to achieve for our children by teaching them science. We are constantly confronted by ethical questions related to science and technology. Every day, newspapers carry articles discussing controversial issues such as nuclear power, genetically modified food, reproductive technologies, global warming and many others. As citizens, shouldn't we be equipped with the skills necessary to evaluate these issues? Do we know enough to engage with these issues and form an opinion on them?

Returning to the issue of abortion in the classroom scenario, we notice that the students raised a wide range of concerns. What kind of knowledge and skills are required on the part of the teacher to handle these discussions? First and foremost, we need to understand that socio scientific issues are controversial in nature. There is no one way to reason about them. In our example, students' positions on abortion fall into two broad categories: a pro-abortion position that believes that parents should decide whether they want to bring a life into the world and an anti-abortion position that believes that life is sacred and begins in the womb. These positions hinge on the ethical question of whether killing a foetus, or the mass of cells formed after fertilisation, amounts to murder.

Although the question of whether abortion amounts to murder is an ethical one, science could clarify some aspects of the controversy. For instance, in the scenario, students are trying to decide whether the foetus is living or not and at which stage a foetus becomes a living thing. One student points out that a cell is alive as long as it can multiply, but the teacher responds by asking what is wrong in removing a multiplying mass of cells. After giving some thought to the teacher's question, another student proposes the criterion that it is wrong to kill anything that feels pain. Answering this question may resolve the controversy for some participants, but not for all. For instance, some students may adopt a stance against abortion if their religion forbids it. We observe this in the scenario, where we have a Christian student Susan who adopts a stand against abortion, which appears to stem from religious beliefs.

The anti-abortion stand that is sympathetic to the parents' choice also needs more discussion. In the classroom scenario, we have a student raising the point that parents ought to have the right to abort foetuses that are likely to be born with disabilities. How do we engage with this point? To be sure, it is not easy to raise a disabled child in a society like ours, where people with disabilities have a tough existence. But does that mean that we avoid bringing people with disabilities into the world at all? Don't they have an equal right to life as any one of us?

Besides the above concerns, there may be many others that could be taken up for discussion, such as how safe abortions are for the mother or the availability of safe abortion services for women who conceive outside the marital relationship. It is definitely not easy for a teacher to handle some of these points in a manner that may be satisfactory to all the students in the classroom. In the next section, I describe some ways in which teachers could conduct socio scientific discussions.

**Ways forward**

As noted, socio scientific issues are complex and controversial in nature. Several kinds of ethical, social and scientific concerns will need to be addressed when teachers discuss these issues in the classroom. When dealing with ethical concerns, teachers need to understand that there is no absolute right or wrong on any of these matters. But that does not mean that any position is acceptable in the classroom. Students need to be encouraged to provide reasons for the position that they present. However, it is also possible that in some cases, students are unable to provide logical arguments or evidence-based reasoning when they present a viewpoint. For instance, as discussed, it is possible that a student who is opposed to abortion on religious grounds cannot provide a scientific argument to support the belief that the zygote is living. The student may also not be open to scientific arguments that oppose his or her viewpoint. It is also possible that these students do not speak up at all in the classroom because they perceive their viewpoints as being in the minority. The teacher needs to find ways to draw out and engage with these positions. One way to draw out students could be through the use of resources like films, documentaries, stories, poems, photographs or newspaper clippings.

Students may also have very emotional responses to certain issues because of specific personal experiences. For instance, a student may strongly react against the issue of abortion of disabled children as she may herself have personal experiences of growing up with a sibling or relative who is disabled. Such personal experiences make students sensitive or defensive when engaging with such issues. Teachers need to be attentive to these aspects.Socio scientific issues also have science-related dimensions that require clarification or evaluation of evidence that could throw more light on some aspect of the controversy. For instance, in the case of abortion, the question of when a foetus becomes a living being is an interesting one from the point of view of science. Is it when the respiratory system develops? Or is it when the nervous system develops and the foetus begins to perceive pain, as a student in the scenario pointed out? Some of these questions may require looking up research studies. Teachers will need to help students look up these studies and help them interpret them and assess their reliability.

Finally, I offer some pointers on how to engage with these issues as and when they arise in the classroom.

- Thoroughly research the issue. Read widely on the issue and on related matters and try to understand all major points of view related to the issue.
- You may come across views that you disagree with. Engage with these views in an open-minded manner. Try to understand the motivations behind these positions.
- Some aspects of the issue may require the use of scientific knowledge or evidence to resolve them. Be prepared to research the needed information with your students.
- Ensure that there is a culture of mutual respect in the classroom, where all students are allowed to speak in turn without the threat of being bullied or ridiculed. Pay special attention to

the voices of girls and students from minority communities.

- Be prepared to be contradicted! It is not easy to let go of control in the classroom. But learning happens only when students are allowed to express their opinions and raise questions.
- Feel free to share your point of view with students. But do so only after students have discussed the matter. If you offer your point of view during the early stages of discussion, students may feel compelled to agree with you, as you are in a position of authority.

**Some concluding**

I hope that this discussion has, to some extent at least, illuminated the importance of socio scientific issues in science education. Before I conclude, let us turn once again to the question of whether we need to introduce these in the science curriculum. The answer depends on what we consider as the important goals of science education. We need to ask ourselves fundamental questions such as: Why are we teaching students science? What kind of science do they need to learn to become informed citizens? What kind of science do they need to learn to become scientists? Can we have a thoughts?

Curriculum that can cater to both the scientists and the non-scientist citizens of the future?

In our science curriculum up to class V, science and social science are not taught as separate subjects. In the Environmental Science textbooks, scientific concepts and social issues are introduced in an integrated manner. After class VI, however, science and social science are treated as separate subjects. This leads to an automatic separation between science and ethics. Finally, when we reach the higher secondary level, we find that the textbooks are full of scientific facts and theories, with very little space to discuss socio scientific issues. Is this desirable? This is a question that I leave to you to consider.

**Further Readings**

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