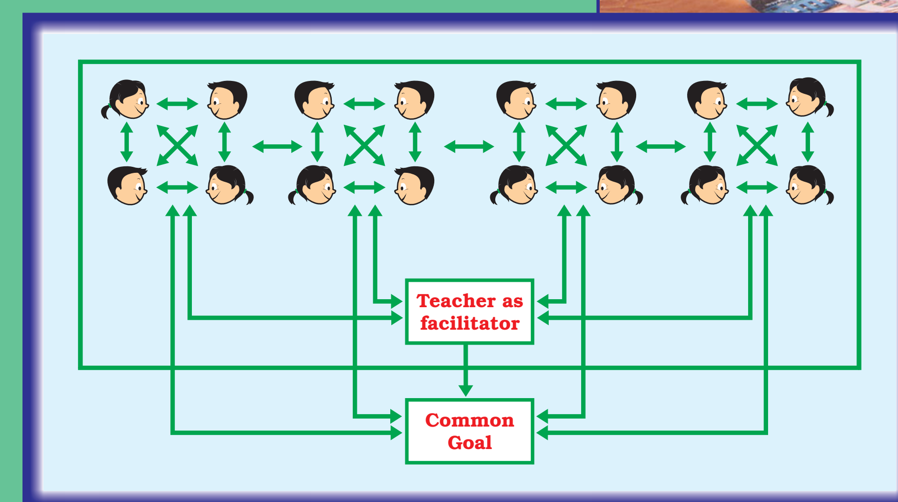
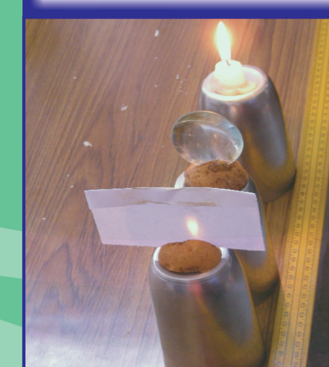
PEDAGOGY OF SCIENCE

Textbook for B.Ed.





PART I

PHYSICAL SCIENCE

PEDAGOGY OF SCIENCE Textbook for B.Ed. Part I

NCERT

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राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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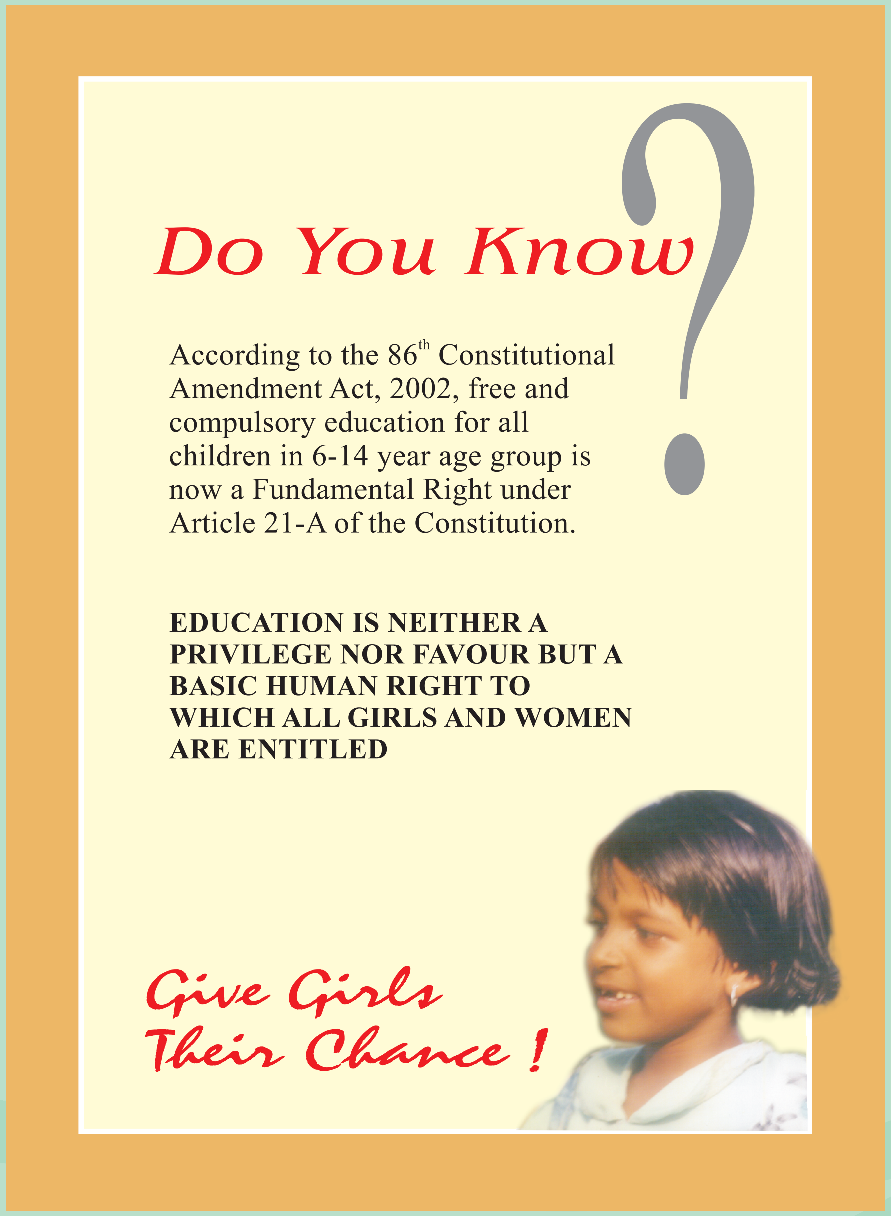

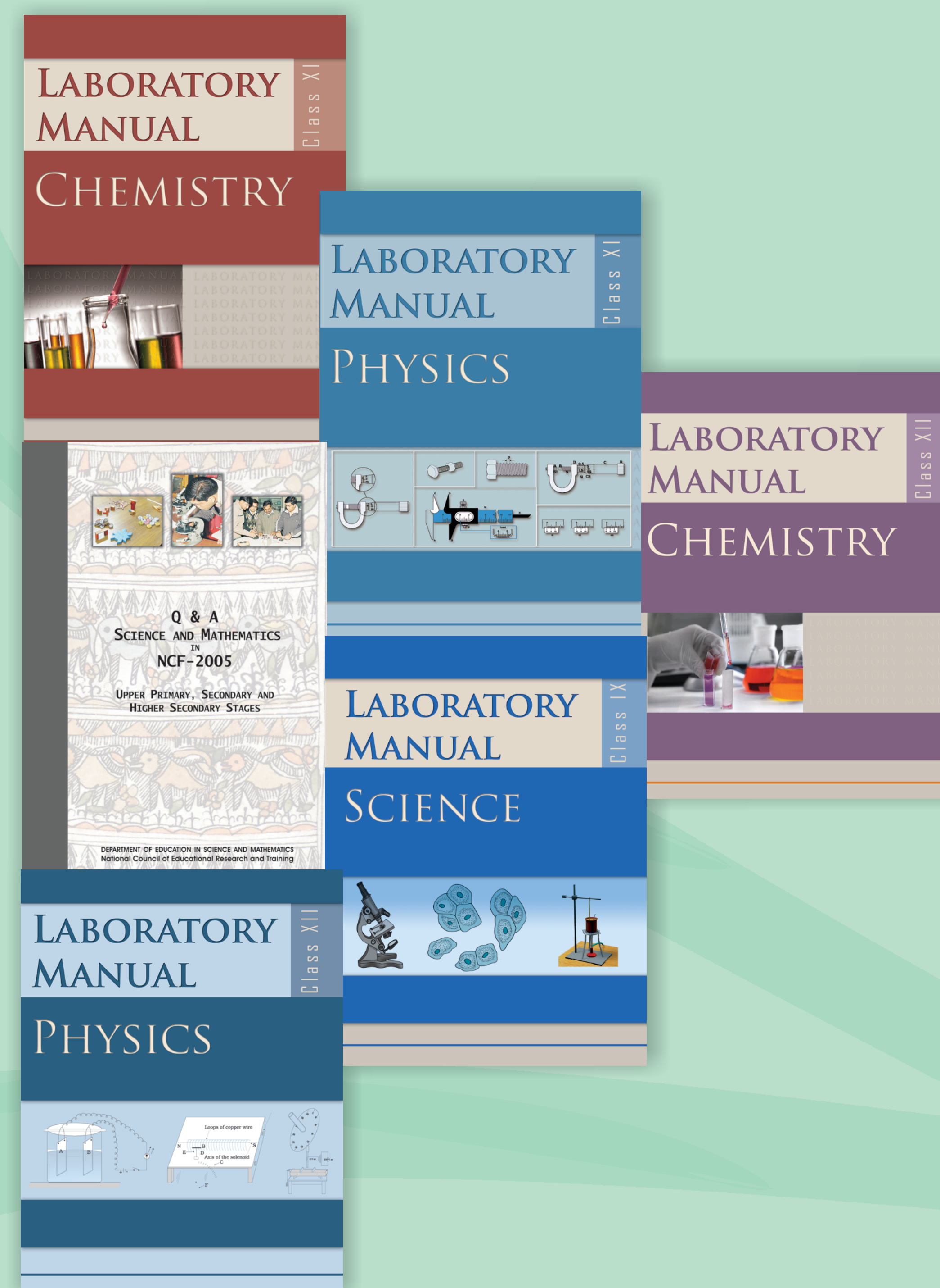

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PEDAGOGY OF SCIENCE

PHYSICAL SCIENCE

PART I

Textbook for B.Ed.

विद्ययाऽमृतमश्नुते

एन सी ई आर टी
NCERT

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The Position Paper on *Teacher Education for Curriculum Renewal* of NCERT observes that the exercise of revising school curriculum, with the aim to revitalise school education, cannot be achieved without addressing the need for creating reflective teaching practitioners. It envisions that the learning inputs in new teacher education programmes will be predominantly learner oriented as it would provide for variety in learning exposures, accommodate differential learning and encourage divergence, reflection and insightful treatment of a learning situation. The exercise of revising a curriculum also provides for critical examination of diverse social conditions of learners, larger issues of social disparity, inequity, gender divide and field specific administration and organisational anomalies. All these contribute to each teacher evolving one's own conviction about teaching as a profession and a professional commitment. In this context the National Council of Educational Research and Training (NCERT) has developed syllabi for teacher education programme that attempt to implement the above ideas. Based on the syllabi all the concerned departments have initiated the development of textbooks to support the student-teachers. In this series, the Department of Education in Science and Mathematics has prepared textbooks entitled *Pedagogy of Science* (Physical Science and Biological Science) and *Pedagogy of Mathematics*. We hope that these books will serve the purpose of teacher education programmes that can engage them in a child-centred system of education.

The success of this effort would be possible if freedom and flexibility are given to teacher-educators, student-teachers and teachers at the school level in their teaching-learning endeavours. Teachers need to recognise that every child learns in her/his own unique way. Therefore, every teacher has to find her/his own way of engaging the learners in the learning process. Teaching-learning of science and mathematics should be closely intertwined with the content and pedagogy of science and mathematics respectively. Involving learners in the process of inquiry and investigation helps the teachers to gain a better insight into the nature of science and mathematics and purpose of science and mathematics education. We hope the textbooks will serve as a guide to teacher-educators and student-teachers in enhancing their professional competencies and motivating learners to learn science and mathematics as a process of investigation and to solve day-to-day problems in a socially responsible manner as a global citizen.

The National Council of Educational Research and Training appreciates the hard work done by the textbook development committees constituted for these textbooks. Several teachers also contributed to the development of the textbooks. We are grateful to their Heads of Department and Principals for making this possible. We are indebted to the institutions and organisations which have generously permitted us to draw upon their resources, materials and personnel.

I sincerely acknowledge and appreciate the hard work done by Dr Shashi Prabha, Professor B.K. Tripathi and Dr R.P. Maurya, member coordinators, DESM and faculty members of NCERT who contributed to the development of the textbooks. I would also like to acknowledge the efforts of Professor Hukum Singh, Head, Department of Education in Science and Mathematics (DESM) for his keen interest and continuous support. As an organisation committed to systemic reform and continuous improvement in the quality of its products and teacher education programmes, NCERT welcomes comments and suggestions which will enable us to undertake further refinement.

Director
National Council of Educational
Research and Training

New Delhi
April, 2011

PREFACE

The National Focus Group on teacher education formed while developing NCF–2005 strongly recommends that teacher education programmes should be redesigned to respond to the school curriculum renewal process and in accordance with the state and regional context in which they are situated.

Existing teacher education programmes neither accommodate the emerging ideas in content and pedagogy, nor do they address the issue of linkages between school and society. NCF – 2005 envisions a teacher education programme that should facilitate prospective teachers to understand that learners are active participants rather than passive recipients in the process of learning. They construct their own knowledge by connecting new ideas to the existing ideas on the basis of activities/materials presented to them. If student-teachers are provided with such opportunities to construct their knowledge, they can appreciate how knowledge is constructed by actively involving the learners in teaching-learning process. This can further help them to become active participants in a wider context of their professional role as teachers.

Science is dynamic, expanding body of knowledge covering ever new domains of experience. It is an organised system of knowledge which is based on inquiry born out of natural curiosity, logical reasoning and experimentation. The role of a science teacher has evolved in recent years from that of transmitter of knowledge to one of facilitator of knowledge. The teacher is also expected to be a participant in the construction of knowledge and to develop in students an understanding of the nature of science.

Keeping in view the above concerns of science and its pedagogy and to bring quality, excellence and acceptance of diversity in the field of science teacher education in the country, the Department of Education in Science and Mathematics (DESM) has made an attempt to develop a textbook on *Pedagogy of Science* (Physical Science). This book is based on the syllabus of the two year B.Ed. programme designed by the NCERT for the RIEs. It is hoped that this book would be equally helpful to prospective teachers of other teacher education institutes of the country and to a wider clientele in the field of pre-service and in-service training in teaching-learning of physical science. The book will also help practising teachers and teacher-educators to update their knowledge of pedagogy and to deal with context based understanding and analysis of their classroom experiences.

This book is intended to be unique in the sense that various aspects of pedagogy of physical science, spread over fifteen chapters, are discussed on the basis of the concrete context of the school and the learners by forging linkages among learners, the context and the content as well as the processes of the subject matter in a seamless manner. Concepts of pedagogy have been illustrated with the help of classroom experiences of practising teachers. This book is not just for reading, but should be used to get actively involved in the teaching-learning process. It is suggested that student-teachers perform a number of activities which can be done while interacting with their classmates, immediate environment and various teaching-learning materials including textbooks of Science, Physics and Chemistry from Classes VI to XII. The idea is that the student-teachers are able to contextualise their teaching-learning experiences. It is expected that this would discourage the tradition of studying the content of the subject matter and pedagogy separately. Many open ended activities have been included with a view that the student-teacher can dwell on them and then try to perform them by sharing their views with others. This will enable them to develop various skills such as communication, team spirit, respect for other's ideas, inquiry and self-reflection.

Keeping in view that knowledge evolves continuously from experiences and is constructed through the active process of exchange of ideas, beliefs and reflection on issues in shared and collaborative contexts, ample opportunities have been provided to student-teachers to revisit the concepts of physical science at Upper Primary, Secondary and Higher Secondary stages.

It is important to adopt such pedagogic practices in science that engage the learners in groups in meaningful investigations – particularly of the problems they perceive to be significant and important. The classroom atmosphere should be such that it provides space for questions, discussions and debates and enhances learners' metacognitive skills. However, no such reform in science education can succeed unless a majority of teachers feel empowered to put it in practice. Teachers need exhaustive training in pedagogy as well as in the content to transact it through observation, experimentation and investigation. With active participation of student-teachers and teacher-educators, the ideas discussed in the book could have a cascading effect on all stages of science teaching-learning in our schools to meet the needs of all the learners in a flexible manner.

The content in this book was prepared through a series of workshops organised by DESM for its development and refinement involving practising teacher-educators, teachers, subject experts from universities and institutes of higher learning and members of the science group of DESM. We gratefully acknowledge their efforts and thank them for their valuable contribution in our endeavour to provide good quality teaching-learning materials to student -teachers and teacher-educators.

I express my gratitude to Director and Joint Director, Professor, G. Ravindra, NCERT for his valuable motivation and guidance from time to time. Special thanks are also due to Dr. Shashi Prabha, Assistant Professor in Physics, DESM for coordinating the programme, and making the manuscript press worthy.

We welcome suggestions and comments from our valued users, especially student-teachers and teacher-educators for further refinement and improvement of this book.

Hukum Singh
Professor and Head
DESM

New Delhi
April, 2011

ABOUT THE BOOK

This book is an attempt to assist you in your pursuit of enhancement of effectiveness, excellence, diversity and creativity in the area of teaching-learning of physical science. We have tried to provide you with some basic ideas and strategies to help you in the development of concepts of physical science among your students. We intend to encourage you to organise learner-centred, activity-based, participatory learning experiences through observation, dialogue, discussion, projects and field work to integrate the learning of physical science with its content and process. This book is meant not only to be read, but to be engaged with. This can be done by your involvement in thinking critically about what it says, performing the suggested activities, reflecting on your experiences, developing motivation to inquire and to look for various resources of teaching-learning.

In order to achieve these aims we have tried to give many examples emphasising basic principles and relating content and process of physics and chemistry at Upper primary, Secondary and Higher secondary stages with its pedagogy. This book contains plenty of activities to encourage you to inquire and reflect on your work as a regular feature and as a continuous process of your professional development. It will also help you to acquire the skills of self-learning and critical thinking in a collaborative set up. You can think of some new activities suited to the teaching-learning situations and academic environment around you. You should try to perform as many activities as you can. However, do not get discouraged if you cannot perform all of the them in the first go. You will get insight into many activities during your practice teaching. It is important that you work on these activities in collaboration with your classmates and communicate your ideas through multiple channels. In some cases you might need to collaborate with the teacher-educator also. While sharing your views and experiences, many a time you will find that your classmates come out with different approaches to an activity as there can be many ways to perform that activity. Similarly, your classmates may respond to an exercise question in different ways as there can be divergent thinking among them. A large number of exercises given at the end of each chapter will provide you an opportunity to reflect on your teaching-learning process of physical science.

Some conventions followed in the book are as under:

- Each activity is meant to highlight the process of construction of knowledge for conceptual understanding as indicated by the jigsaw pattern appended to the activity. The pattern is also meant to highlight the communication among prospective teachers and teacher-educators.
- In the book, 'she' has been used for the learner, teacher and student-teacher instead of he/she for the sake of convenience.
- In order to visualise teacher preparedness in a learner-centred context

where learning goes on in learner specific ways at various paces and with various styles, the word 'teaching-learning' is used instead of teaching. The word 'teaching' has an underlying tone of what a teacher does in a teacher centred class and therefore is not appropriate.

- Some box items are introduced in many chapters to highlight some features of the contents requiring additional attention of the student-teachers.
- Classroom experiences of practising teachers and examples to illustrate the concepts are presented in boxes of a different colour for the ease of reading.

We wish you a joyful reading and learning!

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CONTENTS

PART II

Chapter 1

Nature of Science

1.1 WHAT IS SCIENCE?

Humans are curious by nature. This curiosity has driven them since time immemorial to explore the world around them. Over time, manipulation and controlling nature for the benefit of humans has become an objective of exploration.

Initially the pace of exploration was slow. But with the availability of better tools of exploration in the last few hundred years and also as a result of industrial revolution in the west, the pace of exploration has increased manifold. Unfortunately, the industrial revolution introduced an undesirable element into the exploration of nature. Exploration became a tool for not only modifying and controlling nature for the benefit of all, but also for controlling natural resources for the benefit of a select few.

Humans' exploratory activities have resulted in the accumulation of a vast source of knowledge called natural science. In natural science, we study about nature which means the entire universe. The knowledge is now organised in several disciplines for the convenience of study. This knowledge is based on inquiry, observations and logical extensions, and is testable by experiment or has logically convincing explanation. It is this organised knowledge with inquiry, logical reasoning and experimentation as its central themes, that we call science. Science may rightly be said to be a domain of inquiry.

ACTIVITY 1.1

Is political science a science? Discuss in the light of the definition of science given above. Can they be compared? Give reasons for your answer.

1.2 NATURE OF SCIENCE

Science has certain characteristics which distinguish it from other spheres of human endeavour. These characteristics define the nature of science. These also set the terms on which you can engage with science. These are discussed below.

1.2.1 Science is a particular way of looking at nature

- A morning walker looks at the rising sun, pays obeisance to the sun-god for bestowing the earth with light and energy and may offer prayer to propitiate Him. Another walker with a scientific bent of mind or scientific attitude, while recognising it to be the source of all energy on the earth, may wonder where the sun gets its energy from, tries to understand the process of energy generation and may think of duplicating this process on the earth for the benefit of humankinds.
- At the time of an epidemic, people take to praying and seek divine intervention to save humanity. A scientist, on the other hand, seeks to isolate the pathogen responsible for the epidemic and develops preventive and curative strategies to fight the disease and save people.
- At the time of an eclipse, people pray, observe fast, and give alms as insurance against any ill effects flowing from the phenomenon. A

scientist considers eclipse a natural phenomenon, enjoys the sight and tries to understand what caused the event and investigates whether it could have any ill effects.

ACTIVITY 1.2

Cite two examples from your experience which bring out the difference between the outlook of a common person and a scientist.

1.2.2 Science is a rapidly expanding body of knowledge

Newer disciplines are being discovered and established everyday and the older ones are being enriched by researches being carried out in institutes of higher learning. Not only is the volume of knowledge increasing at a furious pace, but the newer knowledge is also replacing some of the older knowledge. Look around and you notice that the technology at the base of almost everything that you use has been overhauled in the last five to ten years. For example, the audio tape is now almost obsolete; its place has been taken by compact disc, which itself is being rapidly replaced by other media devices. In this respect science is a highly dynamic body of knowledge.

1.2.3 Science is an interdisciplinary area of learning

Science flourished in ancient cultures like Indian, Chinese, Greek, Egyptian and others. But the science as we know today is not older than a few hundred years. In fact, the words science (meaning knowledge) and scientist are of comparatively recent origin. Earlier, science was called *Natural Philosophy*, alluding to the fact that science inquired into all natural phenomena—be they on the earth, be they in the sky, be they under water in the oceans, or be they inside the human body. However, when the volume of knowledge became too large, scientists started specialising in certain areas. It is then that knowledge was organised for convenience into disciplines like physics, chemistry, biology, geology, astronomy, etc. though no natural phenomenon falls completely under just any one of these disciplines. Therefore, there cannot be any rigid demarcation of one discipline from another. Several scientific topics fall under more than one discipline. In fact, at the present time the trend is towards studying more than one discipline, or interdisciplinary subjects. Consider, for example, the new and powerful disciplines like biotechnology, molecular biology and biochemistry which have emerged in recent times that necessitate the study of biology along with physics, mathematics and chemistry. Can you imagine the disease diagnostic tools of today being developed without the experts from the fields of physics, chemistry, biology, mathematics, computer science, and others, pooling their expertise and cooperating with one another?

Let us take an example of thermodynamics which shows the interdisciplinary nature of science.

- **Thermodynamics** is a branch of science which deals with relationships between the various forms of energy and the rules governing their inter-conversion. The zeroth law of thermodynamics is the statement of thermodynamic equilibrium, that is, when two systems at different temperature are brought together, the heat energy is exchanged between the two till the two have the same temperature. In fact, this law forms the basis of the definition of temperature of a system as a whole. Through its first law thermodynamics tells us that the total energy of an isolated system is conserved, it can simply get transformed from one form to another. The second law asserts that heat cannot be transferred from a body at a lower temperature to a body at a higher temperature without providing extra energy. Because of the far reaching consequences of these laws, we need a deep knowledge of thermodynamics in understanding all processes in nature, whether they are physical, chemical or biological processes belonging to different branches of science.

  Let us consider physical processes. Suppose we heat a given volume of water. Its temperature increases. If we keep supplying heat energy, the water starts boiling and then its temperature stops increasing even if we keep supplying heat energy. How do you understand this strange behaviour? You need knowledge of thermodynamics to get the answer. How do the two phases of water— liquid and gas— coexist in equilibrium? Again, we need thermodynamics to get an answer. As another example of a physical process, suppose we wish to cool a room. It would imply that we have to transfer heat from the colder air of the room to the hotter air outside. Thermodynamics tells us that we need to spend extra energy to do so. This extra energy is supplied by electricity which enables an air conditioner to cool the room. As yet another example, let us consider if there is a limit on the efficiency of a heat engine, say the kind that propels a car? Thermodynamics tells us that no engine can be 100% efficient; the maximum efficiency is prescribed by the Carnot heat engine, which is an ideal engine.

  Thermodynamics is involved in all chemical processes too. We have already stated that thermodynamics governs the equilibrium of different phases of matter. How much heat is evolved or absorbed in a chemical reaction, say formation of rust on the surface of an iron object or in the process of photosynthesis, can be calculated by the application of thermodynamics. We cannot understand the behaviour of a mixture of gases, such as the atmosphere of the earth, without an appeal to thermodynamics. This has an important implication— the environmental studies must include the study of thermodynamics.

Thermodynamics is involved in all biological processes also. Take life process such as digestion or respiration or cell division. They all involve exchange of heat energy, and therefore, thermodynamics. Moreover, metabolism in all living organisms is nothing, but chemical process. These systems cannot be studied without understanding the laws of thermodynamics. In fact, specialised subjects such as *biological thermodynamics* have been developed which study thermodynamics of biochemical reactions.

- **Biomolecules** are chemical compounds found in living organisms. For example, carbohydrates, proteins, vitamins, nucleic acid, lipids, etc. Study of biomolecules is closely related to several areas of study such as *biochemistry, molecular biology, bioengineering* and the like. Biomolecular structure can be studied using X-ray crystallography or Nuclear Magnetic Resonance (NMR) spectroscopy which involves understanding of physics.

- **Surface Chemistry** deals with the phenomena that occur at the interface of surfaces. Some of these phenomena that are observable at the interface are *adsorption, corrosion, heterogeneous catalysis, crystallisation,* and *colloid formation*. Let us take the example of *adsorption* which arises due to the fact that surface particles of the adsorbent are not in the same environment as the particles inside the bulk. Inside the bulk, forces acting on the particles are balanced, but surface particles are subjected to unbalanced or residual attractive forces. During *adsorption* there is decrease in residual forces, because particles of *adsorbate* (substance getting adsorbed) attach to *adsorbent* (surface on which *adsorption* is taking place). Therefore, there is decrease in surface energy which is released as heat. Thus, the concepts of *force* and *energy* which are important for understanding *adsorption* in chemistry come from physics. Surface chemistry is closely related to surface physics and surface engineering. Surface physics aims to study the topics like *spintronics, nanostructure, surface diffusion* and surface engineering aims at modifying chemical composition of the surfaces using suitable materials.

ACTIVITY 1.3

Search the resources in your library or on the internet to write a paragraph on the central theme of each of the following subjects – Population dynamics, Material science and Palaeontology. Discuss their interdisciplinary nature.

1.2.4 Science is a truly international enterprise

There is another aspect of modern science that needs consideration, i.e., it is a truly international enterprise. Men and women of all countries participate in the progress of science and its applications. Most big projects in science are undertaken by teams of scientists drawn from many countries. This is because the human and financial resources needed for most big projects are beyond the reach of any single country. The mapping of Human Genome involved scientists from many countries. The Large Hadron Collider, at the European Organization for Nuclear Research (CERN), has been built by scientists drawn from many countries including India. The experiments on this machine is being conducted by scientists from many countries including many Indian scientists. The payloads to carry out experiments on space satellites bear international imprints. International collaboration in most projects is the order of the day. In this sense, science does not belong to any single country or a group of countries, and it would be morally and ethically wrong to deny the fruits of scientific development to any country in the world.

ACTIVITY 1.4

Search for two more examples of international collaboration in science. Share your findings with your classmates.

1.2.5 Science is always tentative

All theories, even the seemingly well-founded ones, can be revised or improved upon, or abandoned altogether whenever new evidence emerges, either as new experimental observations or as new theoretical developments.

- The earliest theories of the universe held the earth to be the centre of the universe. Such a universe was called the geocentric universe. So strong was the belief in this theory that it became part of the religious faith. Those who thought that the Sun was at the centre of the universe were ignored. Elaborate schemes, involving epicycles (several epicycles in some cases), were developed to fit the observations of planets to the *geocentric theory* (Fig. 1.1).

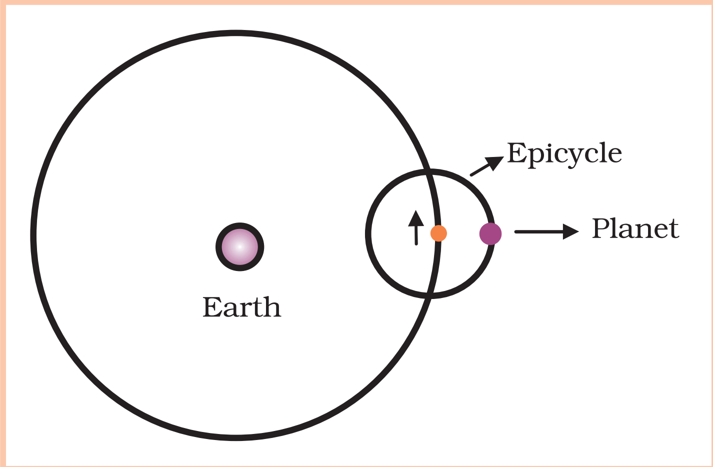


***Fig. 1.1** Geocentric theory: The planet moves on an epicycle whose centre moves around the earth in a circle*

Even when, due to the work of Copernicus, Kepler and Galileo, it became apparent that the Sun must be at the centre of the universe (*heliocentric universe*), scientists were reluctant to let go of the *geocentric theory*. Religious authorities went to the extent of even punishing Galileo for advancing the argument that the earth was not at the centre of the solar system. Ultimately, of course, the weight of argument against the geocentric universe became so heavy that it had to be abandoned and be replaced by the *heliocentric universe*.

- Newton's theory of mechanics held sway for almost two hundred years. So strong was the belief in this theory that it became part of the popular culture. Its key concept of determinism (determinism holds that if we know the position of a particle now, we can determine exactly its position at any time in the future, or in the past) found echo in a new school of philosophy. Yet when observations relating to sub-atomic particles and very massive systems (such as planets and stars) did not fit in the Newton's theory, a new theory came into existence. Particular mention should be made to the precession of the perihelion of the orbit of planet Mercury around the Sun. The new theory, the *theory of relativity of Einstein*, was an improvement over Newton's theory because it could explain the observations relating to the very small and the very massive systems. For ordinary systems, it gave results identical to Newton's theory.

- The vastness of biodiversity has always attracted not just lay persons but also scientists. Depending on their individual backgrounds, they reacted differently. There was a belief that all living beings on earth were created by God. However, Darwin and Wallace in 1850s came up with the idea that life forms evolved on the earth. In other words, the biodiversity pattern has changed over millions of years and that various forms of life can arise only from previously existing forms of life. That, however, leaves the question of the origin of life on the earth unanswered. Scientists have various hypotheses about the rise of the first forms of life on the earth. They are testing these hypotheses to find out the fact. At present, we are far from having any satisfactory answer to this question. However, scientists do believe that life can only arise out of previous forms of life. Before Darwin, the observation that many organisms shared similarities in their phenotype was explained away by the argument that they belonged to a group (taxon). Recall that the phenotype is the sum total of the physical and physiological features of an organism, such as its shape, size, colour and behaviour, which results from the interaction of the genes of the organism with the environment in which it lives. However, the observation of many organisms sharing similarities led Darwin to propose that they are similar, because they come from common parents. Notice how scientific theories move over time.

So, since theories can change over time, **all theories in science have the status as we know them at this instant,** what happens tomorrow we cannot say. This should not be considered a weakness of science. It is actually its great strength. It is the tentativeness, or that the last word has not been said on any topic, that prompts scientists to keep striving to work for new theories or for the improvement of the existing theories, or for new explanations of the known phenomena. Scientists are always searching for evermore refined theories. That is how science prospers. If everything were final, there would be nothing new to discover, and science would never progress.

If scientific theories are always tentative and are likely to change any time, does it mean that we should not make any effort to learn the existing theories? No, we should make every effort to learn the existing theories, for reasons such as to make sense of the world around us we need the current scientific knowledge; to overhaul them when need arises and to incorporate most of the content of the existing theories.

ACTIVITY 1.5

Explain, giving at least one example (other than those given here), how science is tentative in nature. What implication does it have for the study of science?

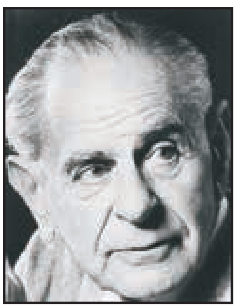
1.2.5(a) Tentative nature of scientific theories

We have seen above how scientific theories take decades, sometimes centuries, to develop into a reasonable shape. Sometimes, it so happens that there are two competing theories trying to explain a certain set of observations related to a certain phenomenon. **Scientists prefer a theory which explains larger number of observations by making fewer assumptions.** This can be said to be scientists' perception of beauty. A theory, which makes a new assumption every time a new phenomenon or a new observation needs to be explained, is obviously not any good.

There was a time when both the *geocentric* and the *heliocentric* theories could explain all the planetary observations existing then. However, geocentric theory had to introduce a new assumption (or a new epicycle) every time a new planetary observation was reported. On the other hand, the beauty of the heliocentric theory was that with just one assumption, that all the planets were revolving round the sun, it could explain every available observation. That is the theory which eventually survived.

In this respect, Newton's theory of gravitation is an excellent theory. It makes few assumptions, and yet is able to explain all the known gravitational interactions.

There is another criterion that a good scientific theory must fulfil. It must be able to predict phenomena that can, at least in principle, prove the theory wrong, or falsify it. This means that any number of observations consistent with a theory cannot prove the theory, but just one observation which goes against the predictions of the theory can falsify it. This view has been asserted by Karl Popper, one of the most influential philosophers of science of the twentieth century. This view is now widely accepted by scientists.



Karl Popper
(1902–1994)

Born in Australia, Sir Karl Raimund Popper is regarded as one of the greatest philosophers of science of the twentieth century. He received a Ph.D in 1928 from University of Vienna and in 1929 qualified to teach mathematics and physics. He served as a Professor at London School of Economics. He wrote extensively on philosophy and history of science. His book *Objective Knowledge : An Evolutionary Approach* published in 1972 popularised the concept of 'falsifiability' as a criterion to distinguish science from non-science. He was knighted by Queen Elizabeth II in 1965 and was elected as a Fellow of the Royal Society in 1976.

To understand what Popper says, suppose we observe a white swan. Then, we observe another one. This, too, is white. Based on these observations, we form a hypothesis that all swans are white. Observation of any number of white swans cannot prove the hypothesis, since we cannot claim to have observed all swans in the world. However, a single observation of a black swan can falsify the hypothesis. It is in this respect that Popper considered Einstein's theory of relativity to be a sound scientific theory. It was possible to deduce from this theory, the consequent attraction of light towards massive bodies. This consequence was highly improbable in the Newtonian theory which was the dominant theory at that time. So, the theory of relativity had within it the seeds of its falsification. The attraction of light by massive bodies was confirmed by Eddington in 1919, when he measured the deflection of light as it passed near the Sun during a total solar eclipse (Fig. 1.2). If this observation had not been made, the theory of relativity would have been abandoned.

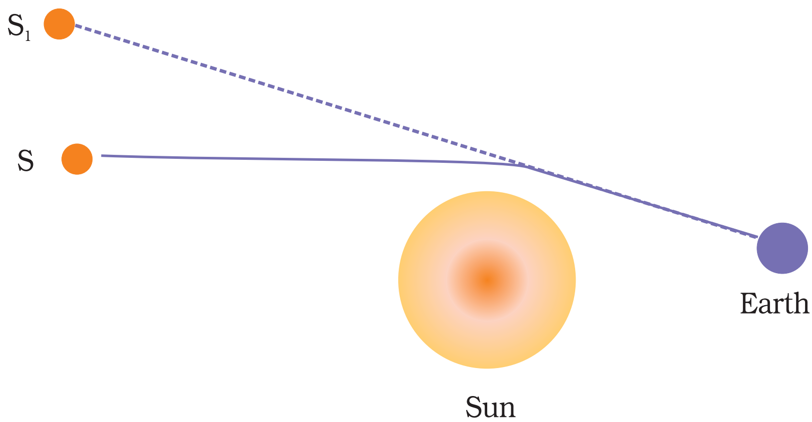
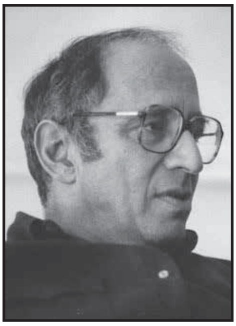


Fig. 1.2 *As the light from the star S passes near the Sun, it gets bent because of the attraction due to the Sun. As a consequence, the star S appears to be at* S_1.

Another influential philosopher of the twentieth century **Thomas Kuhn,** however, maintains that a single contrary or anomalous observation may not falsify a scientific theory. However, when several anomalous observations have accumulated, the existing theory is in a state of crisis. It is time to break new ground and look at all the observations from an entirely new perspective. In this process a new theory is born which subsumes within its fold the results of the existing theory as well as the anomalous results. Science undergoes such paradigm shifts, or revolutions, periodically.



Thomas Kuhn
(1922–1996)

Thomas Samuel Kuhn was an American philosopher and historian of science. He is also regarded as one of the most influential philosophers of science of the twentieth century. He received his Ph.D. degree in physics from Harvard University in 1949. Among a number of publications, his most renowned work is one of the books titled *The Structure of Scientific Revolution* (1962) that he wrote when he was a graduate student at Harvard. He claimed that scientific fields undergo periodic *paradigm shifts*, rather than progressing in a linear way. He received many awards and held honorary degrees from various institutions.

Consider, for example, Planck's theory of black body radiation. In order to reconcile several observations which did not conform to the existing Rayleigh-Jeans law and Wien's displacement law, Planck made a complete break from the past and introduced the revolutionary idea of the quantum of radiation. He asserted that the energy of an oscillator was not continuous, but can be expressed as an integral multiple of a fundamental unit of energy, i.e., $E = h\nu$, where $h\nu$ is the quantum of radiation. Using this idea, Planck was able to explain the radiation emitted by a hot body in its entirety. The Planck's law of black body radiation subsumed both the Rayleigh-Jeans law and the Wien's law as its limits on long wavelength side and the short wavelength side, respectively. This was nothing, but short of a paradigm shift.

Bohr's theory of the atom was another break from the past. It postulated stationary energy states for the electron, the states in which the electron does not radiate energy while revolving round the nucleus, contrary to the classical notions. This, too, marked a revolution in science.

Whatever the view we take of the development of scientific theories, **the fact remains that scientific theories are tentative and are always subject to change.**

ACTIVITY 1.6

Look for other instances in the history of science where a paradigm shift took place. Explain one such shift in your words.

1.2.6 Science promotes scepticism; scientists are highly sceptic people

Scientists are highly sceptic people. Scientists look at everything with suspicion. Every new observation or a new theory is received with a lot of scepticism. It leads to a lot of debate among scientists. A new observation is accepted only when experimental observations have been checked by independent individuals or groups at various places with identical results. Similarly, a new theory is accepted when theoretical calculations have been repeated by other scientists independently with identical results. **In this debate the status of the scientist who proposes something new does not matter; science breeds a truly egalitarian culture.**

One of the stories making headlines in scientific circles in 2011 was *Nobel Laureate Retracts Two Papers.* The story said that the scientist who shared the Nobel Prize in physiology in 2004, has retracted (taken back) two scientific papers after she and her colleagues were unable to repeat the findings reported in those papers. So, it does not matter who you are (even Nobel Laureates are not spared); if the results reported by you cannot be reproduced, they are not acceptable.

These checks and counterchecks also help check frauds. **Scientific process presupposes that scientists will acquire, analyse and report data honestly.** However, sometimes temptation for power and drive for achievement overpower good sense, and some scientists do indulge in fudging, cooking or misreporting data and the results derived from that data. But the game does not remain hidden for long and the fraud is exposed.

One of the most well known recent cases of scientific fraud relates to the research conducted on stem cells. During a particular year the scientist published many papers in highly respected science journals. Among the many claims he and his team made, some were:

- creation of an embryonic stem cell by somatic cell nuclear transfer method;
- creation of 11 human embryonic stem cells using 185 eggs; and
- cloning of a dog.

This work made the scientist world famous. But soon enough trouble started when his own associates expressed reservations on his work. Investigations showed that all 11 of the stem cell lines were fabricated. Two of his papers in the prestigious journal *Science* were retracted by the editor of the journal. Soon after that the scientist himself apologised for his wrong doings. He was sacked from the university and later he was tried on charges of embezzlement.

Another recent incident of fraud concerns a brilliant physicist. He was publishing papers at an incredible rate during 2001–2002. In 2001 he claimed in a paper in the highly respected journal, *Nature*, that he had produced a transistor at the molecular scale. This created a lot of excitement in scientific community because of its tremendous importance for technology. Other groups also got into the act and tried to repeat his experiments, but did not succeed. This created suspicion in their minds.

What gave away the game for the physicist was that two identical graphs were found in two of his research papers dealing with different topics. Other anomalies were also discovered. Eventually, the scientist had to admit that in many of his papers, data was incorrect and in some papers he had falsified data.

The point to be emphasised is that the tradition that the scientific work must be reproducible takes care of many of these misconducts. This is a kind of self-regulation by the scientific community to keep fraudulence under check. Another incident, though not fraud, which occurred in 1989, shows how replication of work is essential to gain its acceptance by scientific community.

We know that fusion is a process in which lighter nuclei fuse together to produce a heavier nucleus. A lot of energy is released in the process. This is the process that takes place inside the stars and produces energy for them. Many groups of scientists have been trying for long to replicate the process on earth. If these experiments are successful, we could get a source of abundant energy. However, the scientists have not met with much success. The fusion process in the laboratory occurs at a very high temperature, $\sim 10^7$ K. Therefore, it was exciting news when two scientists announced that they had observed fusion at room temperature, hence the name *cold fusion*. Several laboratories in many countries jumped into the fray to try and observe cold fusion. However, nobody has succeeded so far, though a few people are still trying. It is generally believed that the scientists made a mistake in their measurements and there is little evidence for the existence of *cold fusion*.

ACTIVITY 1.7

Search the internet for misconduct in science; you will come across many interesting cases. Describe briefly any one of these cases.

1.2.7 Science demands perseverance from its practitioners

There is another characteristic of science that is not generally highlighted, but is really important for its development and progress. This is the tenacity and perseverance that science demands from scientists. A scientist, getting an inspirational idea or a creative thought on making a chance observation, or otherwise, has to persist with the idea to take it to its logical conclusion. Sometimes, the scientist works alone all the way to the discovery or invention, while at other times the scientist can make only a beginning and then others join him/her in developing the idea further.

A chance observation that two lenses placed in a certain arrangement make far off things appear nearer was made by an unknown spectacle maker. Hans Lippershey (1570–1619) of Holland heard of this device. He refined it to make a practical telescope and disseminated its design. Galileo heard of this invention and set out to make a telescope for himself. With this telescope he observed the phases of planet Venus and the nearest moons of Jupiter. It is well known how his observations ushered a revolution in science. He was able to convince scientists that the sun could be at the centre of the solar system. Kepler, Huygens, Newton and many others contributed towards the improvement of telescope.

It is a tribute to their hard work, and that of the generations of scientists following them, that today we have very large and efficient telescopes on land as well as in space. Not only that, we have today telescopes working in several other regions of the electromagnetic spectrum, such as at X-ray, infrared and radio wavelengths.

Take another example– Wilhelm Rontgen, a German physicist, was experimenting with discharge tubes on 8 November 1895, when he chanced to observe that a fluorescent screen kept some distance away from the discharge tube glowed whenever he applied voltage to the electrodes of the tube. It was known at that time that the discharge tube produced cathode rays when potential difference is applied between the electrodes. To prevent cathode rays from leaking from the tube, Rontgen had covered it with card-board. So, when he observed the fluorescent screen glow, he thought he had discovered some invisible rays coming from the tube which caused the screen to glow. A less diligent person might have ignored this observation as a fluke, but not Rontgen. From that day till the end of the year, he virtually lived in his laboratory with his apparatus, verifying the properties of the observed radiation. He convinced himself that what he had observed was a reality indeed. At the end of this period he invited his wife into the laboratory and got the picture of her hand. The picture showed only the skeleton. He then announced his discovery of the unknown rays, calling them X-rays. For his discovery Rontgen received the Nobel Prize in physics in 1901. We all know how important X-rays are to diagnostic procedures today.

The discovery of X-rays by Rontgen also underlies the importance of attuning to science which a training in science should ensure. Without this attuning, Rontgen would not have grasped the significance of his chance observation.

Another such example is the discovery of penicillin by Alexander Fleming. Fleming was a physician by training and enjoyed reputation as a brilliant researcher. At any given time he was engaged in research on many topics, so his laboratory was always cluttered. In 1928, on returning from a vacation, he was clearing culture-laden petri dishes when he noticed a mould growing in one of the dishes. He was surprised to notice that the area immediately surrounding the mould was clear of the culture. He surmised that the mould had produced a chemical which had killed the bacteria that produced the culture. He tried this chemical on many other types of bacteria. Once convinced of the antibiotic nature of the chemical, he announced in 1929 the discovery of penicillin. We all know how important penicillin is for the treatment of bacterial diseases. For his efforts, he received the Nobel prize in 1945.

ACTIVITY 1.8

Collect a few more instances of discovery involving a chance observation followed by hard work. Share your work with your friends.

1.2.8 Science as an approach to investigation and as a process of constructing knowledge

Most investigations in science involve some form of scientific method. It shows creativity of humankind in seeking solution to its problems. The approach used by the scientists in the study of astronomy and ecology is observation and prediction. In microbiology they rely on laboratory experiment focused on cause and effect relationship. This is a glimpse of the process by which science works. The essential elements of this process have been collected in what is known as scientific method. These elements are discussed below.

(i) Observations: Scientists usually have to find cause and effect relationship. Suppose a scientist needs to explain a phenomenon, or may be a problem has been posed to him which he needs to solve. For this purpose the scientist carries out observations of the phenomenon that is to be explained. These observations are repeated several times, sometimes by more than one person and at more than one place, so that there is no doubt about their correctness. Observations are properly recorded and studied to discover if there are any hidden patterns.

We interact with the world outside through our sense organs. Whatever we observe through our sense organs (see, listen, smell, taste, feel) is information. Besides senses, we have mind which processes this information by registering, classifying, generalising, etc. and converts it to knowledge. Our mind sorts out the information on the basis of differences and places them into various categories on the basis of similarities, which later on can be recalled for use in different situations, thus becoming a part of knowledge.

Here you can notice that knowledge is constructed by the individual herself by applying her own mental abilities. It depends on the individual's ability to observe and her intelligence to process the information. Individuals in the same environment may possess different levels of knowledge. Basic unit of knowledge is fact.

In science, any repeatedly verifiable observation becomes a fact. In this respect, the meaning attached to 'fact' in science is different from the meaning of 'fact' in day-to-day usage as part of ordinary language. Let us see some examples of 'facts' in science.

- 'The rainbow is always seen in a direction opposite to that of the Sun' is a fact, because every time or any time one observes a rainbow, it is found to be in a direction opposite to that of the Sun.
- 'A ball rolling on any surface comes to a stop after some time' is a fact, because it has been repeatedly verified.
- 'The reaction of copper sulphate with zinc resulting in the production of zinc sulphate and copper' is a fact because this reaction has been repeatedly observed in the laboratory.
- 'The occurrence of photosynthesis, by which plants convert carbon dioxide into organic compounds using the energy of the sunlight,' is a fact too.

ACTIVITY 1.9

Cite a few more examples of scientific facts.

Now consider some observations about a particular object at different times.

- It is a piece of a solid.
- This solid has a shining appearance (lustre).
- This solid can be beaten into sheets (malleable).
- This solid can be drawn into wire (ductile).
- This piece of solid can conduct heat and electricity.
- This solid produces ringing sound when struck with another solid.

You may have observed many solids with the same or similar properties with difference in colour and lustre or any other property.

The above listed observations have been made at different times. These can be combined into a simple sentence as:

This solid has lustre, it is malleable and ductile, it conducts heat and electricity and produces ringing sound when struck with another solid.

Here you have associated all the properties with a given solid. You would like to remember this solid with one word or name. This name will then represent that solid with all these properties. The name of the solid is 'Metal'. 'Metal' is an example of a concept.

Metal, Acid, Solid Water, Glass, Paper, Pen, Chair, Molecule, Mixture, Salt, Solution, Combustion, Evaporation, Oxidation, Waves, Interference, X-ray, Semiconductors, etc. are some other examples of concepts. Thus, concept is a word, an idea or a mental image of an object, process or phenomenon.

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

Direct experiences and observations are essential for the formation of many concepts. Each individual has to interpret natural phenomenon in terms of her own experiences. Learner's environment and prejudices may affect concept formation. Sometimes much time elapses between the original experience, the development of the concept and its application.

Many concepts can be combined in a way to convey meaning which can be tested and verified universally. Then they become a principle. For example,

- Metals expand on heating.
- Liquids evaporate on heating.
- A body can be moved from one place to another by applying a force on it.
- Archimedes Principle.
- Bernoulli's principle, etc.

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

ACTIVITY 1.10

What different concepts are involved in Bernoulli's principle? Discuss.

(ii) Hypothesis: The observations of a phenomenon, or facts, raise certain questions, such as, 'what caused it to happen?' Or, 'why did it happen this way and not in any other way?' On the basis of the answers to these questions, the scientist thinks of a tentative explanation or formulates a hypothesis. For example, to explain how we see things, a hypothesis was formulated in the ancient times that the human eyes emit rays which fall on objects to make them visible. Let us take an example from everyday life. Suppose you switch on your television set and its screen is still dark. Your first guess, a hypothesis, could be that there is no electric supply. If electric supply is there then you make another guess, a second hypotheses. This could be that the switch is faulty. In science, all hypothesis are testable. One of the most important features of science is that it requires hypotheses to cast into a form that can not only be verified but also significantly proved wrong.

(iii) Prediction from a hypothesis and its testing by experimentation: Prediction of science does not mean telling something about the future which has not occurred in the past. It is about foretelling results of an experiment which might be obtained and have remained or not remained unnoticed to throw some light on the scientific phenomena. The hypothesis is analysed to make predictions which are verifiable by experimentation. In the context of the hypothesis given in the above paragraph to explain how we see objects around us, one of the predictions of the hypothesis, which can be tested experimentally, can be that the objects will be visible even when no light from an external source is falling on them. This prediction needs to be tested to confirm or discard the hypothesis.

If experiments show that the hypothesis formulated is not correct, a new hypothesis is formulated and subjected to experimental verification.

It is possible that a hypothesis can make more than one predictions. Such a hypothesis is accepted only when all the predictions made by it have been confirmed by experimentation.

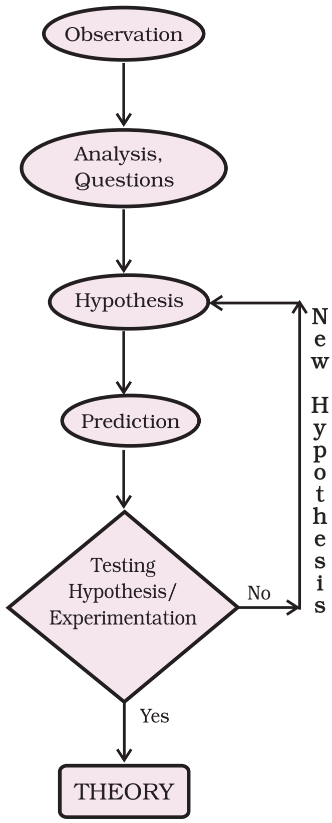


***Fig. 1.3** Flow chart of scientific theory*

(iv) Scientific Theory: The process of formulating and verifying hypotheses continues till all the predictions of a hypothesis (or a group of related hypotheses) are found to be correct by experimentation

(Fig. 1.3). At this stage possible generalisations of the hypothesis are looked for. The results are communicated to the scientific community through publications in scientific journals. The results are then open to experimental scrutiny by scientists all over the world. If the results pass the test of reproducibility, the hypothesis along with generalisations is then promoted to the status of a theory. **Notice the rigorous testing of a scientific idea; such rigour is the corner stone of the scientific method.**

Newton's theory of gravitation is a prime example of a theory which passed all the tests set for it, including generalisation to universal application. The theory is expressed in the form of an equation,

$$F = G\frac{M_1 M_2}{r^2}$$

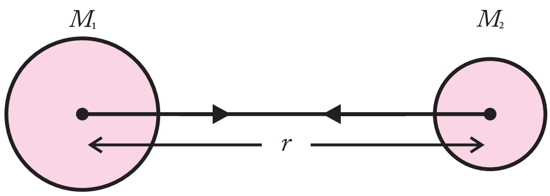


Fig. 1.4

which gives the magnitude of the force between two masses M_1 and M_2 placed at a distance r from each other (Fig. 1.4). G is gravitational constant.

Theories are often expressed in terms of a few concepts and equations. Newton's theory of mechanics or Newtonian mechanics is expressed in terms of concepts like inertia, momentum and force and in the form of well-known equations.

For example:

- The second law of Newton is expressed as

$$\vec{F} \propto \frac{d\vec{p}}{dt}$$

where $\vec{F}$ is the force and $\vec{p}$ is the momentum.

- The first law of thermodynamics, which expresses the conservation of energy, is expressed through an equation

$$dU = dQ - dW$$

where dU is the change in the internal energy of a system, dQ is the heat supplied to the system, and dW is the work performed by the system.

The equations which express the laws are then called the **laws of nature**, meaning that they are applicable universally. These laws help us not only to understand nature but also to explore it. The integrated whole of these laws provide us a framework to understand a part of nature in a particular perspective and constitute a theory. Laws are concise verbal statements or mathematical expressions.

There is difference between theory and law. **A law may describe a single action or phenomenon whereas a theory explains a set of phenomena.** A theory is a set of interconnected concepts, assumptions and principles giving a systematic explanation of natural phenomena. More importantly, a theory should predict new phenomena which are verifiable by experimentation.

ACTIVITY 1.11

Observe the laws given in the textbooks of Class XI and Class XII physics/chemistry. Discuss do they satisfy the characteristic given above.

Some theories make huge demands on our imagination for their understanding. It is useful then to present them in the form of models. They represent phenomena or abstract ideas that we cannot see. Thus, models help us to conceptualise ideas.

One of the most well-known examples is the Bohr model of an atom (Fig. 1.5). In this model, the atom consists of a positively charged nucleus which contains almost all the mass of the atom, and electrons orbiting the nucleus in the same way as the planets orbit the sun.

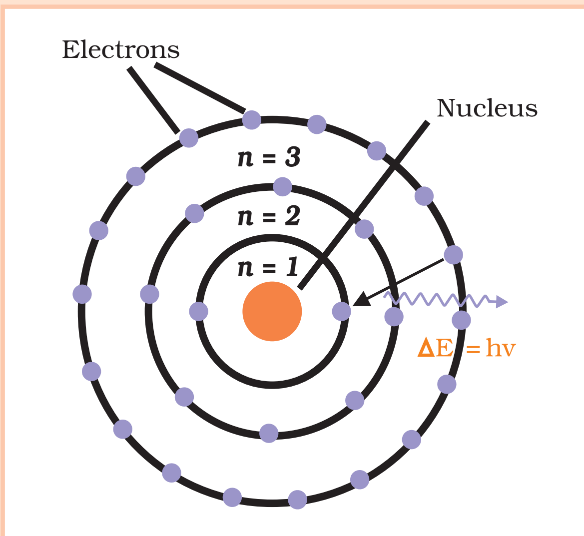


***Fig. 1.5** The Bohr model of an atom*

The utility of the Bohr model is that it allows us to calculate quantities like the energy levels of the electrons and the energy radiated or absorbed when an electron jumps from one energy level to another. **However, it must be clearly understood that a model has only a limited validity and the reality could be much different.**

As we have discussed above, let us emphasise that no theory is final. It is always tentative, subject to modification or even rejection in the light of newer observations. Newton's theory of mechanics, extremely successful for a long time, failed to explain the observed changes in the orbit of planet mercury round the sun and was overtaken by the theory of general relativity. Remember that in most day-to-day situations, Newton's theory is still quite valid; it is only in special situations that we have recourse to the theory of relativity.

A few words need to be said about **experimentation.** The outcome of an experiment may depend on several variables. If the scientist allowed all the variables to vary at the same time, the result would not be understandable at all. So, an experimentalist studies the influence of one variable at a time as a function of another variable by keeping all other variables constant. In other words, he conducts a controlled experiment. For example, both volume and pressure of a gas are affected by its temperature. If we allow both variables to change with temperature, the result of the experiment will be difficult to understand. So, in a controlled experiment we keep the pressure constant and study the effect of temperature on volume. In another controlled experiment, we keep the volume constant and study the variation of pressure with temperature.

1.3 SCIENTIFIC METHOD: A CRITICAL VIEW

A few points about the scientific method need to be emphasised.

- Scientific method is not a prescribed pathway for making discoveries in science. Very rarely the method has remained a key to a discovery in science. **It is the attitude of inquiry, investigation and experimentation rather than following a set steps of a particular method that leads to discoveries and advancement in science.**
- Sometimes a theory may suggest a new experiment; at other times an experiment may suggest a new theoretical model. Scientists do not always go through all the steps of the method and not necessarily in the order we have outlined above. Investigation in science often involves repeated action on any one or all steps of

the scientific method in any order. Many important and path-breaking discoveries in science have been made by trial and error, experimentation and accidental observations. Both Rontgen and Fleming, in the examples given above, did not set out to discover X-rays and penicillin. They did not go through the scientific method described above. They had qualities of healthy intuition and perseverance which took them to their goal. Besides intuition, informed guesswork, creativity, an eye for an unusual occurrence, all play significant role in developing new theories, and thereby in the progress of science.

- The validity of a hypothesis depends solely on the experimental test and not on the prestige, stature, faith, nationality or any other attribute of the personality of the person who proposes the hypothesis. There is no authority in science that tells you what you can criticise and what you cannot criticise. In this sense, science is a highly objective discipline.
- A scientific method with its linear steps makes us feel that science is a 'closed box approach' of thinking. However, in practice science is more about thinking 'out of the box'. There is tremendous scope of creativity in science. Many times in science, an idea or a solution to a vexing problem (a problem that causes lots of discussion) or an interpretation of observation appear to arise out of creativity and imagination. The stories of Archimedes, Kelkule's, etc. come to our attention.
- People keep floating all kinds of theories. Often they couch their arguments in scientific terms. This confuses a large number of people, and hoodwinks them, but we should remember that a theory is valid only if it passes the test of experimentation, otherwise it may just be a matter of faith. The theory of evolution advanced by creationists is not based on scientific argument and is not consistent with scientific method; it is based entirely on faith.
- The scientific method imposes operational limitation on science. It does not help us to make aesthetic or value judgment. For example, frequency of the colour of paintings may be determined but there is no scientific method to label the paintings of two artists as *great* or *not so great*. Scientific method does not prove or refute the ideas such as *existence of god* and *existence of life after death*.
- Following scientific method does not ensure that a discovery

can be made. However, the skills learnt in making observation, analysis, hypothesis, prediction from a hypothesis and its testing by experimentation help us in developing scientific attitude.

- **All of us will benefit immensely if we imbibe the spirit of scientific method in our personal lives.** The scientific method tells us to be honest in reporting our observations or experimental results, keep an open mind and be ready to accept other points of view if our own view is proved wrong. These values form what is called the **scientific temper** or **scientific attitude,** or **rational thinking.** The adoption of these values is very important for an individual as well as for a society to get rid of superstition and prejudice. **In fact, it will make the world a much better place to live if individuals and societies often examine their beliefs and prejudices in the light of the modern scientific knowledge and try to get rid of those beliefs and prejudices which are not in consonance with this knowledge.**
- Scientific method is a logical approach to problem-solving and repeating or replicating other scientist's work. For example, as discussed above the recent claim of cold fusion discovery could not be replicated.

The way for developing rational thinking is quite simple:

- We should be sceptic and accept something only when we are convinced that it is logical or has passed the test of experimentation.
- We should keep our ears, eyes and minds open. We should be ready to appreciate others' point of view. We should try to convince others or get convinced by them without rancour and ill feeling.
- Accept an idea only when we are sure that it is logically sound. Suppose, for example, somebody tells you that the radiation emitted by your cell phone is harmful. Before accepting this view uncritically, you must consider the following— the amount of radiation emitted by the cellphone, the frequency at which this radiation is emitted, the safe dose of this radiation at this frequency, etc. If you do not have the expertise, you could consult experts or reliable scientific literature on this matter. The point is that we should not accept anything uncritically without investigation/verification/convincing argument in its favour. Persons possessing scientific temper think rationally and do not fall easy prey to superstition and prejudice.

ACTIVITY 1.12

Suppose your name is Seema. Somebody tells you to make it Sima for better luck. How would you react?

ACTIVITY 1.13

Suppose somebody tells you that for better health you should sleep resting your head in the south direction. What would be your reaction?

1.4 AN ILLUSTRATION OF HOW SCIENCE WORKS

In science, experimentation and theory building complement each other. Sometimes a new experiment throws up observations which force modification in an existing theory or demand the development of an altogether new theory. At other times, theoretical development in a theory predicts new phenomena which needs to be verified by experiment. This interplay between theory and experiment is a fascinating facet of the scientific process.

History of science is replete with examples of such interaction between experimentation and theory. Just to illustrate, we briefly review the development of our understanding of the *Nature of Light*.

Light (in the form of sunlight and moonlight) must have hit man almost as soon as he developed consciousness. He must have been speculating about its nature since then. The earliest thoughts on its nature seem to have come from Indian seers and philosophers. In the sixth–fifth century BCE, they described light rays as streams of high velocity atoms of *tejas* (fire) and said that depending on the arrangement of the atoms, light can exhibit different characteristics.

The above ideas were only qualitative. The first quantitative theory was proposed by Euclid, the great mathematician, in third–second century BCE. In his book *Optica* Euclid noted that light rays travel in straight lines. Using geometry, he explained why distant objects appear smaller and nearby objects appear bigger. He also described laws of reflection. Interestingly, he believed that vision is caused by the light rays emanating from the eye and falling on the objects seen. However, Aryabhatta pointed out in the fifth century CE that an object is seen when it is illuminated by light from an external source.

Reflection and refraction of light are the oldest phenomena known to us. Much of the discussion on the nature of light during renaissance centred around these phenomena. In the seventeenth century, Huygens proposed that light consists of waves. Later Newton proposed that light is composed of particles or corpuscles. Both of them were able to explain successfully the phenomena of reflection and refraction. However, when in the early years of the nineteenth century, interference of light was observed by Thomas Young, wave theory of light received a big boost because interference (and later diffraction and polarisation of light) could be explained only if light propagated as waves. Wave theory was firmly established when Maxwell in the latter half of the 19th century showed theoretically that light must be electromagnetic wave.

Almost a hundred years after Young's experiment, Einstein revived the idea of Newton's corpuscles to explain the photoelectric effect. He gave the name photons to the corpuscles of light. Science was at the threshold of a new idea. It was realised that light has dual nature. It behaves sometimes as waves and sometimes as particles. In phenomena like interference, diffraction, and polarisation, light behaves as waves, while in phenomena like photoelectric effect, pair production and Compton scattering light behaves as if consisting of particles. There the matter stands today. A future theory may provide a more satisfactory answer.

This brief account shows how science progresses. Notice that the path of development is not uni-directional. An idea may receive support at sometime, while at another time it may receive a setback. Through such jumbled movements do scientific theories emerge. However, they always remain tentative, to be replaced by better theories. Notice also that persons from many nationalities are involved. So, science can never belong to a country or region. It belongs to the whole mankind.

1.5 ROLE OF A SCIENCE TEACHER

You may have wondered at the significance of studying the nature of science in the pedagogy course. Science teachers face a challenging task to inculcate the essence of the scientific enterprise among students. Students should be made conversant with scientific way of knowing and thus constructing their knowledge in science. Teacher should structure the learning experiences in such a way that the nature of science becomes an inherent part of all teaching-learning situations. Historical aspects of the development of scientific concepts should be emphasised. It would help students to appreciate how science evolved by human endeavour and resulted in the development of various technologies. It is important to simultaneously reduce the overload of memorising facts which often cause a disinclination towards science.

Laboratory work in science, infused with the spirit of inquiry, provides students with hands-on experiences and develops a scientific attitude which is one of the important aims of teaching-learning of science.

The role of the science teacher is crucial to the development of scientific temper among students. **It goes without saying that the teacher should herself be competent in the area she teaches; she must be familiar with all the aspects of the nature of science; and she must have imbibed scientific temper herself.** Such a teacher can exemplify the content of scientific temper from her everyday conduct. From time to time, she can engage her students in discussions to develop scientific temper among them, and foster the values hidden in scientific method like truth, honesty and open-mindedness. She can help her students retain and sharpen further the sense of inquiry by allowing them to explore their environment and encouraging them to ask questions, even if sometimes these questions appear trivial. By her own enthusiasm for science she can transmit the excitement of doing science. During teaching- learning she can convey that science is tentative and nothing is fixed or final and the quest for progressive refinement of theories and explanations continues in which the students can participate at that time and later when they grow old.

Activities such as projects, field work, paper reading along with laboratory work and discussion would encourage students to do science. This in turn, would help them to learn the skills associated with the inquiry and processes of science such as observing, measuring, hypothesising, predicting, analysing and communicating.

ACTIVITY 1.14

Outline a few steps you would take to inculcate scientific temper among your students.

While assigning projects the science teacher can remind her students of honesty of reporting their observations. She must herself be ready to appreciate if students report their findings honestly even if they lead to wrong results. She could also tell her students that they are not too young to do good science. She can relate to them a recent report that a science journal in England published about a scientific study by 8 year olds. The students were from an elementary school and they were investigating, as a part of their project, the way bumblebees see colours and patterns. The scientific organisation, which is more than 300 years old and which includes some of the world's most eminent scientists, said that the children reported findings that were a genuine advance in the field of insect colour and pattern vision. So, the science teacher must impress on her young students that projects assigned to them can lead to fruitful investigations and results, provided these are done in the spirit of genuine inquiry.

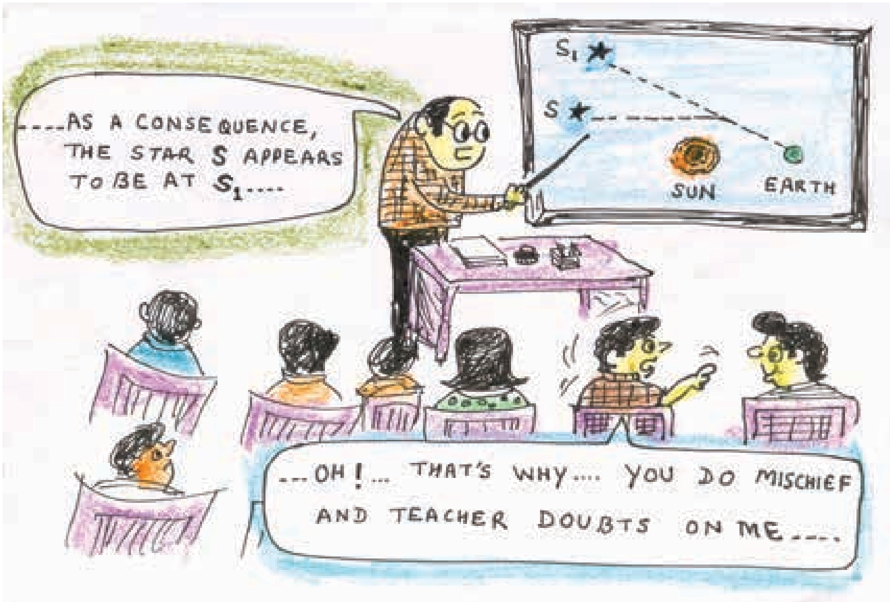
We have discussed above that people from all over the world contribute to the progress of science. As a science teacher you must instil confidence in your students that they can also contribute in this process.

Understanding the nature of science is a valuable goal of science education and must be reflected in the process of assessment. It is not enough to merely examine students' learning of facts and principles of science. It is necessary to assess their spirit of inquiry, sceptic attitude towards existing ideas, and tendency to try out new ideas.

A consequential aspect of science education is understanding how science is related to technology and society about which we shall study in Chapter 2 *Science and Society*.

1.6 SUMMARY

We learnt in this chapter that science is an organised system of knowledge which is based on inquiry born out of human curiosity, logical reasoning and experimentation. As humans face nature in its various manifestations, this knowledge is expanding fast, not the least with the help of international collaboration. Broadly speaking, science is a particular way of looking at nature, which may also be called scientific attitude. One of the most important characteristics of science is that even the most established theories can be modified, or even abandoned, if new experimental results do not fit into the existing theories. This promotes scepticism among scientists. They look at every new observation or theoretical calculation with a healthy dose of scepticism and do not accept it till the result has been reproduced by many scientists at various places. Reproducibility is one of the important criteria for a scientific result to be acceptable. It is believed that scientists, in their exploration, employ inquiry and scientific method. The method consists of several steps, such as observation of a phenomenon, formulation of hypothesis to make predictions which are verifiable, verifying hypotheses, formulation and propagation of a theory flowing from the hypotheses. The theories are often expressed in terms of a few concepts and equations. The use of scientific method and inquiry in daily life promotes scientific temper and rationality. That is why it has been emphasised that all of us should imbibe the spirit of scientific inquiry in our personal lives. Finally, the importance of the role of the science teacher has been stressed in inculcating the spirit of inquiry among their students and orienting them towards developing scepticism and scientific temper.



EXERCISE

1.1 Explain how her own understanding of the nature of science helps a science teacher in promoting meaningful learning among her students.

1.2 Is all scientific knowledge empirically based? Discuss.

1.3 Some people maintain that scientists and scientific knowledge are subjective. Discuss giving supporting evidence.

1.4 How are observations and inferences different? Are there cases where they are not different? Cite examples.

1.5 In what sense are scientific laws and scientific theories different types of knowledge? In what sense are they related?

1.6 To what extent is scientific knowledge socially and culturally embedded? In what sense does it transcend society and culture? Discuss with relevant examples.

1.7 How does the notion of scientific method distort how science actually works? Discuss with suitable examples.

1.8 Some people believe that at the time of solar eclipse, the sun emits some special rays harmful to pregnant women. As a student of science how would you convince people that there is nothing special about the sun at the time of eclipse?

1.9 List any two discoveries in physical science. Discuss tentative nature of the theories behind those discoveries.

1.10 Is astrology (Feng Shui, Reiki,....) a science? Discuss.

1.11 Sumit, a student of Class VII shows keen interest in the study of science. One day he asked his teacher, "I want to discover/invent something in science, but I feel everything has already been discovered/invented. What should I discover/invent?"

What do you think the teacher should tell Sumit, so that his attitude of curiosity and inquisitiveness is fostered.

Chapter 2

Science and Society

2.1 INTRODUCTION

One of the important aims of education is to help students to become responsible democratic citizens of the country. The responsibility of science teachers is not only to teach facts, principles and processes of science, but also to facilitate students to discharge their social responsibilities and preserve democracy as well. They should appreciate how science and technology have developed and are affected by many diverse individuals, cultures and societies. They need to be encouraged to appreciate and participate in the responsible use of science and technology for the benefit of society, to visualise future of our nation and to become sensitive and responsible citizens. It is important to develop critical thinking in them about interconnectivity of science, technology and society in order to maintain a healthy and sustainable society. Students should be encouraged to develop a scientific vision about different issues, about acquiring and processing information, about scientific and technological developments and their relevance to everyday life and long-term implications to society. Therefore, science teachers should view their obligations in a broader perspective.

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

Humans' inquisitiveness and usefulness of the knowledge of science are the two main factors which have led them to continuously strive to understand the behaviour of nature and use the knowledge of science to make their life more comfortable. In doing so humans systematised knowledge by classifying it into various fields of their activities, built concepts to understand the behaviour of nature and found various ways to exploit it. All these endeavours of the humankinds resulted in a new discipline known as science. Science has influenced and benefited us so immensely that it has become indispensable. At the same time, the society has also helped science to grow.

Science enhances the quality of our life and it is visible in all walks of life. Since science has been developed by people who are part of a group, society or a country, it is expected that their social, psychological, political, economic perceptions could change the course of development of science.

Societies have changed over time and consequently science has evolved over the time. **The need of the society has always played a very important role in the development of science.** The practice of *Alchemy* (derived from the Arabic word *al-kumis*) was developed as a result of efforts to discover *Elixir of Longevity* for granting a person eternal life. Investigation into such an *elixir* was responsible for alchemy being practised on large scale in countries like ancient Egypt, Mesopotamia (modern Iraq), Persia (modern Iran), Japan and India. Alchemists believed in miraculous transformation of materials. They thought that base metals could be converted into gold by removing impurities. *Alchemy* later on became chemistry. So we see that areas of research in science many a time make a dramatic shift according to the need of the society.

The emergence of philosophy and science in Greece came around 450 BCE. Plato's work was based on the highest human faculty—reasoning. He did not believe in working with hand which arrested the progress of the experimental science. However, his student Aristotle laid down the standard professional approach to scientific records. The arguments he used was of two types – *dialectical*, that is based on logical deduction and *empirical,* based on practical considerations. He developed a school of organised scientific inquiry on a scale far exceeding anything that had happened in the past. He single-handedly developed science as a collective organised enterprise. The work was considered so much sacrosanct that all accepted this work, including individuals, societies, political and religious systems of that period.

Advancement in science and technology has raised several complex issues in today's globalised world. There are many science and technology oriented issues and problems which can be tackled by scientific community in collaboration with various organisations, communities, societies and government. Examples of such problems are community health, population growth, safety from natural and human-induced disasters and infectious diseases, depleting natural resources, endangered wild life concerns, etc. Each member of society needs to consider these problems as his/her own. **Students should not only be aware of relevance of scientific discoveries and development in their everyday life, but use it for the benefit of society.** Students should be made to realise that social development affects progress in science and vice versa. Students should enrich their educational experiences by understanding the impact of issues such as energy crises, genetic engineering, nuclear testing, Genetically Modified (GM) crops, and global warming on the modern society for its well-being.

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

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

So, in addition to providing higher quality education, many other values have to be inculcated in our students. This facilitates them to be successful in their profession and contribute their best services to the society. Such a successful person in society adjusts well and becomes a good citizen.

Even though one can study any course of one's choice, the society/ government select some thrust areas for providing research. For instance, soon after independence, the country gave priority to research in the field of agriculture and health. So it led to green revolution and white revolution. Production of crops were facilitated by improved fertilisers, seeds and pesticides. Later, there was a boost to industrial sectors. Sometimes research in defence may get priority in the time of national crisis. Now extensive research is being conducted in the field of information technology and bio-technology. Lots of progress have been made in communication technology, space technology, etc. India is advancing in the area of knowledge and technology. Education thus has a very vital role in knowledge dissemination and progress of society.

Therefore, science responds to the needs and interest of the society in which it is practised and developed. Science is practised by people who are often sensitive to the needs and interests of the world around them. Vaccines, for example are developed by scientists who are sensitive to the current needs of the society. Let us do the activity given below before discussing areas in which science has served the society locally as well as globally.

ACTIVITY 2.1

Why should a science teacher appreciate the interconnectivity of science, technology and society? How can she use this knowledge to help students become socially responsible citizens? Discuss with your friends in a group and present your views in the class.

ACTIVITY 2.2

Find the underlying principle of any new discovery in science by scanning a newspaper report. Discuss its likely influence on society.

2.2 PHYSICAL SCIENCE AND SOCIETY

Physical science includes study of Physics and Chemistry. Physics is one of the most fundamental sciences. It deals with the study of matter and energy. Study of physics helps us to understand other sciences such as chemistry, biology, geology, astronomy, medical science, environmental science, and host of other sciences. At the same time, development of other sciences contributes to the development of physics itself. The connection between physics, technology and society can be appreciated by a number of examples. The principle of lever has been utilised for thousands of years in the development of civilisation. The ancient Egyptians used levers to lift obelisks (tall, pointed, tapering, four-sided stone pillar, set up as a monument or landmark) weighing in excess of 100 tons. The discipline of thermodynamics arose from the need to understand and improve the working of heat engines. Invention of the steam engine initiated the industrial revolution in England in the eighteenth century, which had great impact on the course of human civilisation.

An Obelisk

Sometimes technology generates new physics; at other times physics generates new technology. An example of this is the wireless communication technology that followed the discovery of the basic laws of electricity and magnetism in the nineteenth century. The most significant area to which physics can contribute is the development of alternative energy resources. If nuclear fusion experiment is controlled to generate energy, it can bring prosperity in our society.

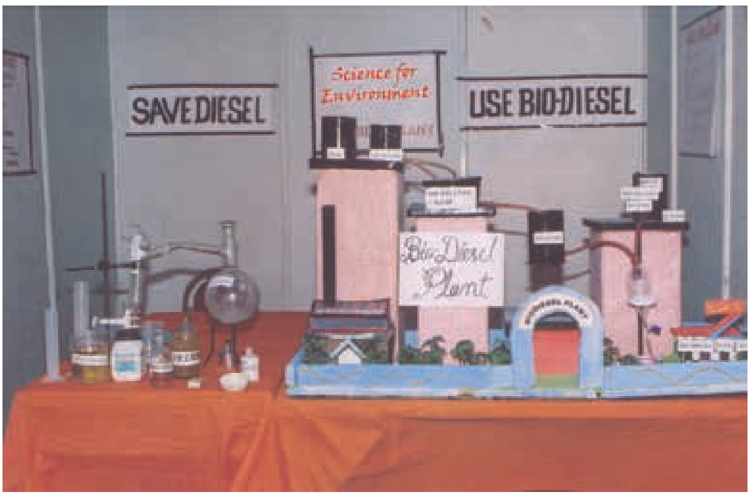
Chemistry is the study of properties and uses of matter. It is also one of the basic sciences and serves as foundation to understanding of biochemistry, molecular genetics, physics, geology, physiology, etc. Many new chemicals developed by chemists have important significance to society. To name a few,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

Nylon was developed as a synthetic material in 1931 without using any natural raw material derived from plant or animal. It was prepared from coal, water and air. This fibre is strong, elastic and light. Since it was lustrous and easy to wash, it became very popular for clothes. Due to this, a number of scientific and technological advancements took place. Agricultural chemicals like herbicides, fungicides, humic acid (to increase availability of plant nutrients), Indole acetic acid (a plant hormone that prevents fruits from dropping prematurely) and calcium sulphate (to reduce soil acidity) play important roles in the way we cultivate crops. Identification of specific fuel additives and suitable vehicular material has made transportation efficient and comfortable. Similarly, electronics and computer technology have become advanced because of a variety of chemicals having specific properties. However, the advantages of these scientific developments have not been unalloyed. Many new developments have adverse effects on our environment. The study of these effects and the need to minimise damage to the environment gave rise to a new branch of science — **environmental science**. Thus, we find that the interaction between science and society is never unidirectional.

2.2.1 Physical science for environment

Environment may be defined as everything present in the universe. The universe has air, water, soil, the sun, the moon and many other things. It also has plants, animals, rivers, mountains, deserts and oceans. Broadly, the environment has four segments— atmosphere, biosphere, lithosphere and hydrosphere.

In science we deal with facts, concepts, principles and events that take place in nature. For a long time, human beings remained part of natural system and were not able to tinker with it. Then they started making tools, invented fire, grew agricultural crops and domesticated



Models on environmental issues

animals. At this stage, humans depended so much on agriculture that they could be called **agricultural beings**. Later they started using nature and its resources according to their own demands. These developments transformed human into **industrial beings**. At the present time, the volume of knowledge is growing at such a tremendous rate that it will not be an exaggeration that we have transformed ourselves into **knowledge beings**. By their activities, humans brought about changes in the environment. These activities have resulted in pollution of the environment. Of late, pollution has started increasing at an alarming rate. This has drawn attention of the general public as well as of the scientists.

The study of the effects of contaminants (physical, chemical, biological) on the environment has also become part of science. Scientists started working on the prevention of pollution of water, air, soil, noise, and that caused by radioactivity. For example, the use of Compressed Natural Gas (CNG) as fuel in preference to petroleum and diesel helps in reducing the level of carbon dioxide in the air. Also, alternative sources of energy such as wind, solar, nuclear, biogas, tides, geothermal, etc. have been explored and their use is growing. These measures would surely decrease pollution and the global warming. Ozone depletion has been checked largely by aerosols, such as Chlorofluro Carbons (CFCs), so that they do not accumulate in the atmosphere. Suitable devices have been installed at the sites to map the noise pollution and to control it. Various measures have been employed for controlling the radioactive pollution.

Thus, science is essential for the study of the environment and its improvement.

A new branch of chemistry, **green chemistry**, has been developed to prevent the environment from degeneration. Green chemistry is about utilising the existing knowledge and principles of chemistry and other sciences to reduce the adverse impact of human activities on the environment. Application of the existing knowledge for reducing the chemical hazards due to developmental activities is the foundation of green chemistry. It involves intervention at both the product and process level. If a product is harmful, we search for its substitute. If the substitute is not available and the product has to be used, we try to improve the process of its production or find an alternative process, so that the product becomes environment friendly. One such example is the chlorine gas, which was used earlier for bleaching paper. These days, hydrogen peroxide with a suitable catalyst, which promotes its bleaching action, is used. Tetrachloroethene ($Cl_2C = CCl_2$) was earlier used as solvent for dry cleaning the clothes. The compound contaminates the ground water and is also a suspected carcinogen. Now a days liquified carbon dioxide with a suitable detergent is used in place of halogenated solvent which results in less harm to the ground water. Ethanal (CH_3CHO), used in chemical industries in large scale is now commercially prepared by one step oxidation of ethene in the presence of ionic catalyst in aqueous medium, with a yield of 90%.

$$2CH_2 = CH_2 + O_2 \xrightarrow[\text{Pd(II)/cu(II)(in water)}]{\text{Catalyst}} 2CH_3\ CHO\ (90\%)$$

ACTIVITY 2.3

Identify a current newspaper article related with environmental issue (Hint: nuclear energy, food security, climate change, etc.). Frame a few questions and conduct a debate in the class around those questions.

ACTIVITY 2.4

Make a list of actions you would undertake to reduce air, water and soil pollution in your surroundings. You may discuss in a group to make this list.

2.2.2 Physical science for health

One indication that the progress of a society has taken place is that its members are healthy. In fact, the disease and poverty form a vicious circle. People are poor, because they are suffering from various diseases; people are suffering from various diseases, because they are poor. Therefore, for poverty alleviation, it is essential that people should be healthy. Science has served humankinds to a great extent for making its members healthy and free from diseases. It has formalised the consumption of various nutrients such as proteins, carbohydrates, vitamins, fats, minerals, etc. in requisite amounts for a person to remain healthy. Science has also generated preventive measures so that people do not fall prey to diseases like malaria, tuberculosis and hepatitis B. Various techniques of diagnosis have also been developed, e.g., MRI, ECG, X-rays, ultrasonography, etc. Use of antibiotic medicines has freed humankind from several dangerous diseases such as syphilis, tuberculosis, leprosy. Recently a number of drugs have been developed for chemotherapeutic treatment of cancer. Radiotherapy has proved to be a potential therapy for removing tumour. The scientists from various countries have contributed in this area. India's contribution to health sciences is quite important.

In ancient times, Indian society was quite alert to the physical and mental health of its members. Indian medical tradition dates back to Vedic times. Ayurveda, perhaps the most ancient medical system, originated in India. It still thrives in India. Ayurveda centres and spa resorts, providing treatment of many ailments based on this system, are quite popular and now exist in many countries of the world. The system claims not to treat the sickness but the sick. It seeks to treat the patient holistically, restoring not only the physical but also the mental health of the person.

Dhanvantri was thought to be the pioneer in developing Ayurveda. In the sixth century BCE, Sushruta had studied human anatomy. He invented the technique of contraction of cataract. His works have been compiled in *Sushruta Samhita*. It describes some 1120 illnesses, 700 medicinal plants, more than 100 medicinal preparations from mineral and animal sources. About 125 surgical instruments have also been mentioned in *Sushruta Samhita*. Sushruta described diabetes *(madhumeha)* as a disease which affects primarily people who are obese. In this connection, Sushruta emphasised the role of physical activity in maintaining good health.

Charak, who lived in second or third century BCE, is considered to be the King of physicians in India. He was acquainted with all branches of medicine, including surgery and psychotherapy. His works, compiled in *Charak Samhita,* are an authoritative source for ayurvedic treatment. In this volume he has described the medicinal properties and functions of 100,000 herbal plants. He has stressed the importance of diet and physical activity on the mind and body.

Physical science has contributed a lot in reducing human suffering by the discovery of anesthesia and antisepsis to be used for surgery and various medicines such as painkillers, antibiotics, sedatives, etc. to relieve pain and sufferings.

One of the humming issues facing the society today is to provide health care to all its members. Scientific vision of health care and understanding the intricacies of modern medicines can enable the society to choose the right path to follow.

Project 2.1

Prepare a list of questions that you would like to know from a doctor (ophthalmologist, orthopaedician, dentist, etc.) about the use of technology in the treatment of diseases. Conduct an interview with the doctor and observe the tools and machines used by him/her. Identify the scientific principle behind those technologies and present a report in the class.

2.2.3 Physical science for peace

Science has brought about an overall betterment of life of humankinds. Therefore, it is expected that if there is full collaboration in knowledge acquisition in pure and basic sciences and in the application of scientific knowledge to the developmental work, peace should rule on every aspect of human psyche. **The scientific knowledge is universal and it has no boundaries.** Utilitarian side of science also has no conflict in serving the society. Therefore, if peace does not prevail in the society, there must be other factors which have to be controlled. One of the indicators of peace is absence of violence. However, if violence spreads amongst individuals, groups of individuals, states and groups of states, it means there must be some contradiction amongst them. Therefore, feeling of peace has to be brought about at all levels, i.e. individual, society and state. These levels are interactive and their relationship is complex. At the level of the individual, we have to change the social and psychological perceptions. At the level of the society, we have to change the psychological and historical perceptions, and at the level of the state we have to change the perception of political and geographical distance.

Students need to be encouraged to visualise future of our nation to become sensitive and responsible citizens. It is important to develop critical thinking in them to maintain a healthy and sustainable society. **Children need to be encouraged to appreciate and participate in the responsible use of science and technology for the benefit of society.** They should also have a scientific vision about different issues and abilities to acquire and process information about scientific and technological developments relevant to their everyday life and their long-term implications on society. Students should be made aware about interrelationship and interdependence of various scientific issues in the global and economic contexts so that they can form a wider perspective of justice, peace and non-violence.

The psychology of a individual can be changed by suitable intervention of science. The individual should develop scientific temper through logical discussion and application of scientific method and inquiry. The individual should appreciate that scientific development for the benefit of humanity takes place when there is peace all around. It must be remembered that the discovery of the law of gravitation by Isaac Newton, invention of the steam engine by James Watt, invention of electric motor by Michael Faraday, invention of radio transmission by Guglielmo Marconi and inventions of hundreds of machines by Thomas Alva Edison were possible only during the time of peace in the world. One should understand that the inventions and discoveries made during war time are for self-interest and for showing supremacy of some State/States over others. However, scientific knowledge and its developmental enterprises must be used for the welfare of humankinds which in turn would bring peace in the society.

ACTIVITY 2.5

Conduct a role play on various objects like computer, television, mobile, etc. depicting their effective uses.

ACTIVITY 2.6

Search the library, internet to collect information about peaceful uses of nuclear energy in following areas and prepare a report : power, food production and preservation, medicine, water desalination.

ACTIVITY 2.7

Identify an issue of ethics in science and organise a debate on it.

2.2.4 Physical science for equity

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

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

However, education is sometimes blamed for bringing about an alienation of the child from the family and society. This could be due to low levels of literacy and schooling in the country and the fact that a large number of students are first generation learners. This problem could be addressed, if curriculum is so designed that there is a close connection between the local environment and the learning of the child. Education embedded in the locally situated technology too, should serve to integrate the child into the society. Sensitivity in the choice of contexts, of equipment and pictures, could go a long way towards reducing inequality. **Diversity should be valued in school and each individual should be respected.** We can take example from the diversity in the properties of elements. All the elements have different identities; nonetheless, they have some common characteristics. On the basis of that characteristic, all elements are placed in different groups in the periodic table.

Researches have shown that the boys and girls perform equally well in science learning. Therefore, no gender bias should be practised in the classroom and in allotting scientific work to the students. All attempts should be made to motivate the parents to encourage their girl children to opt for science. Teachers, teacher educators, textbook writers and educational administrators must be made sensitive and responsive to gender-related issues. Problems and exercises, as well as texts that reflect the reality of women's life and experiences should be an integral part of teaching-learning experiences. Laboratory work that highlights scientific dimensions of domestic work also, for example chemistry in kitchen should be taken into account.

There are other sections or groups of students whose needs are special. This is a specialised area and technique of teaching needs to evolve in consultation with the concerned experts. The education system should display conviction and mobilise required resources to put in place support systems that will help these children to overcome their inadequacies in learning science in a meaningful manner. For example, books written in Braille must be made available to all visually-challenged students.

Science teacher should develop in all students including those with special educational needs the ability to analyse the options available, and to facilitate the possibility of making informed decisions.

We should appreciate that science being a study of nature, does not have any scope for such biases. For using science as a tool to foster equity the following actions and options should be adopted.

- Use science curriculum as an instrument of social change to reduce the socio-economic divide and to help fight prejudices related to gender, caste, religion and region. Teacher should highlight the contribution of scientists belonging to various nationalities, castes, races, colours, and sex, etc. during teaching-learning of science.

- Content of the curriculum should promote respect for diverse lifestyles. In the Indian context, teacher should highlight diversities prevailing in India due to varying weather, temperature, cultural, economic and social conditions.
- Emphasise gender sensitisation of teachers both at the pre-service stage and during in-service training to promote gender fair science education.
- Use Information and Communication Technology (ICT) as a powerful tool for bridging the social divide in education and as an opportunity equaliser. The teacher should make use of various ICT and web tools to overcome any disadvantage her students might be suffering from.
- In the activities of the science clubs, all students should be encouraged to participate in visits to exhibitions, museums or science parks.
- During practical work, importance should be given to all students irrespective of gender, religion, caste, colour, etc.
- Using an inclusive language which is simple and which uses words from both the rural and urban areas.

ACTIVITY 2.8

Review a textbook of science in terms of visibility of girls in the figures and examples in the book.

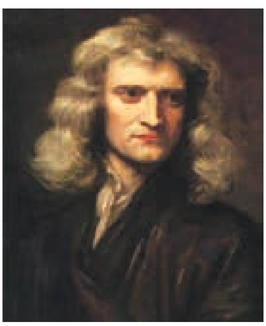
2.3 ROLE OF THE TEACHER

- Promote collaboration and stronger connection between different classes of the school, various schools, with other educational institutions and in general with communities to help develop a healthier society.
- Use diverse pedagogical practices in teaching-learning of science. Care should be taken to remove discrepancies against students on the basis of learning difficulties, identity, gender, caste, religion, etc.
- Science exhibition, science club, science drama, field visit to various places and out of the school activities should be promoted to foster social values along with enrichment of educational experiences.
- Knowledge of science should not breed a culture of arrogance and superiority. Team spirit, respect for other's idea and collaborative work culture should be developed in students.

- Social climate of the school and classroom has a deep influence on the learning process of the learners. An atmosphere of trust would make the classroom a safe space where students can share their experiences, where conflict can be acknowledged and constructively questioned, and where resolutions, however tentative, can be mutually worked out. Collaboration in all forms rather than competition should be promoted.
- Ours is a democratic country where people of different caste, creed and gender live together. Teacher should value, elicit and try her best to incorporate experiences of all students in teaching-learning of science. Students should be made aware that their experiences and perceptions are important for further enhancing their understanding of science.
- Science teacher should be fair and scrupulous to all and not act out of her vested interest. She should be appreciative of our composite culture and national identity from an international perspective.
- Teacher should keep herself up to date in the area of latest development in science, technology and their impact on the society.
- Developing scientific attitude in students is one of the important obligations of science teacher.
- Teacher must develop warm and supportive relationship with students and colleagues and must collaborate with other teachers especially with science teachers in designing and sharing experiences of teaching-learning of science.

2.4 CONTRIBUTIONS OF SOME EMINENT SCIENTISTS

Students should appreciate how science and technology have developed and is affected by many diverse individuals, cultures and societies. All scientific developments are due to the contributions of great minds in the field of science. Societies at large have benefited due to their contribution. Let us now see contribution of some eminent scientists.



Isaac Newton (1642–1727) was born in Woolsthorpe, England in 1642, the year Galileo died. His extraordinary mathematical ability and mechanical aptitude remained hidden from others in his school life. In 1662, he went to Cambridge for undergraduate studies. A plague epidemic in 1665 forced the university town to close and Newton had to return to his mother's farm. There in two years of solitude, his dormant creativity blossomed in a deluge of fundamental discoveries in mathematics and physics: *binomial theorem for negative and fractional exponents, the beginning of calculus, the inverse square law of gravitation, the spectrum of white light,* and so on. Returning to Cambridge, he pursued his investigations in optics and devised a reflecting telescope.

In 1684, encouraged by his friend Edmund Halley, Newton embarked on writing what was to be one of the greatest scientific works ever published : *Principia Mathematica*. In it, he enunciated the three laws of motion and the universal law of gravitation, which explained all the three Kepler's laws of planetary motion. The book was packed with a host of path-breaking achievements: *basic principles of fluid mechanics, mathematics of wave motion, calculation of mass of the earth, the sun and other planets, explanation of the precession of equinoxes, theory of tides,* etc. In 1704, Newton brought out another masterpiece *Opticks* that summarised his work on light and colour.

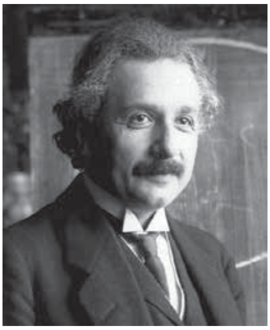
The scientific revolution triggered by Copernicus and steered vigorously ahead by Kepler and Galileo was brought to a grand completion by Newton. Newtonian mechanics unified terrestrial and celestial phenomena. The same mathematical equation governed the fall of an apple to the ground and the motion of the moon around the earth. The age of reason had dawned.

John Dalton (1766–1844) was born in a poor family in 1766 in England. He began his career as a teacher at the age of twelve. Seven years later he became a school principal. In 1793, Dalton left for Manchester to teach mathematics, physics and chemistry in a college. He spent most of his life there teaching and researching. In 1808, he presented his atomic theory which was a turning point in the study of matter. Dalton consolidated his theories in his book *New System of Chemical Philosophy*.

He kept daily weather records from 1787 until his death in 1844 and published his first book *Meteorological Observations* (1793). His interest in meteorology led him to develop theories about water vapour and mixed gases. He studied a variety of weather phenomena and about the instruments used to measure them. He is also known for his work on colour blindness.

J.C. Bose (1858–1937) developed an apparatus for generating ultrashort electromagnetic waves and studied their quasi-optical properties. He was said to be the first to employ a semiconductor like *galena* as a self-recovering detector of electromagnetic waves. Bose published three papers in the British magazine, 'The Electrician' in 1895. His invention was published in the 'Proceedings of the Royal Society' on 27 April 1899 over two years prior to Marconi's first wireless communication on 13 December 1901. Bose also invented highly sensitive instruments for the detection of minute responses by living organisms to external stimuli and established parallelism between animal and plant tissues.

Albert Einstein (1879–1955), one of the greatest physicists of all time, was born in Ulm, Germany. In 1905, he published three path breaking papers. In the first paper, he introduced the notion of light quanta (now called photons) and used it to explain the features of photoelectric effect. In the second paper, he developed a theory of Brownian motion, confirmed experimentally a few years later and provided a convincing evidence of the atomic picture of matter.



The third paper gave birth to the special theory of relativity. In 1916, he published the general theory of relativity. Some other significant contributions of Einstein are : the notion of stimulated emission introduced in an alternative derivation of Planck's blackbody radiation law, static model of the universe which started modern cosmology, quantum statistics of a gas of massive bosons, and a critical analysis of the foundations of quantum mechanics. In 1921, he was awarded the Nobel Prize in physics for his contribution to the theoretical physics and the photoelectric effect.

Niels Bohr (1885–1962), a Danish physicist received his Ph.D. from the University of Copenhagen in 1911. He then spent a year with JJ Thomson and Ernest Rutherford in England. In 1913, he returned to Copenhagen where he remained for the rest of his life. He contributed to atomic structure and quantum mechanics. In 1920, he was named Director of the

Institute of Theoretical Physics. After first World War, Bohr worked energetically for peaceful uses of atomic energy. Bohr was awarded the Nobel Prize in Physics in 1922 in recognition of his work on the structure of atoms. He received the first *Atoms for Peace* award in 1957.

He presented his work in 115 publications; three appearing as books in english: *The Theory of Spectra and Atomic Constitution,* University Press, Cambridge (1922); *Atomic Theory and the Description of Nature,* University Press, Cambridge, 1934; *The Unity of Knowledge,* Double day & Co., New York, 1955.

Chandrasekhara Venkata Raman (1888–1970) was born at Thiruvanaikaval, near Trichinopoly, Madras Presidency to R. Chandrasekhara Iyer and Parvati Ammal. On February 28, 1928, through his experiments on the scattering of light, he discovered a phenomenon in spectroscopy, later named as the Raman Effect. It was instantly clear that this discovery was an important one. It gave further proof of the quantum nature of light. Raman spectroscopy is based on this phenomenon.

He won the 1930 Nobel Prize in Physics for his work on the scattering of light and for the discovery of the effect named after him. In 1934 Raman became the director of the Indian Institute of Science, Bangalore, where two years later he continued as a professor of physics. Other investigations carried out by Raman were experimental and theoretical studies on the diffraction of light by acoustic waves of ultrasonic and hypersonic frequencies (published 1934-1942), and those on the effects produced by X-rays on infra red vibrations in crystals exposed to ordinary light. Raman retired from the Indian Institute of Science in 1948 and established the *Raman Research Institute* in Bangalore, Karnataka a year later. He served as its director and remained active there until his death, at the age of 82.

Louis Victor de Broglie (1892–1987) French physicist who in 1924, put forth revolutionary idea of wave particle duality. His theories were confirmed by the discovery of electron diffraction by crystals in 1927 by Davisson and Germer. The idea of wave particle duality was further developed by Erwin Schródinger into a full-fledged theory of quantum mechanics commonly known as wave mechanics. He was conferred with the Nobel Prize in Physics for his discovery of the wave nature of electrons. He was awarded the first Kalinga Prize by UNESCO in 1952 for his efforts to explain aspects of modern physics to the layman. His other works were on Dirac's electron theory, the general theory of spin particles and applications of wave mechanics to nuclear physics.

Bimla Buti is a plasma physicist. She initiated and founded the Plasma Science Society of India. In the capacity of Director of Plasma Physics at the International Centre for Theoretical Physics (ICTP), Trieste, Italy, from 1985 to 2003, she was the first Indian woman Fellow of TWAS (Third World Academy of Sciences) and the first Indian woman Physicist Fellow of Indian National Science Academy (INSA). She got the Vikram Sarabhai Award for Planetary Sciences (1977), the Jawaharlal Nehru Birth Centenary Lectureship award, 1993, the Vainu Bappu International Award in Astrophysics, 1994, and the Lifetime Achievement award of the University of Chicago in 1996. After her official retirement from Physics Research Laboratory (PRL), Ahmedabad as Professor of Astrophysics. she spent four years at the Jet Propulsion Laboratory (NASA), California Institute of Technology.

She is now settled in Delhi and continuing her research and also doing some social work through the Buti Foundation which she founded in 2003.

Professor Bimla Buti was born on 19 September 1933 at Multan in Pakistan, migrated to Delhi at the time of partition. She completed her Ph.D. in 1962 from University of Chicago and was privileged to work with Nobel Laureate Prof. S.Chandrasekhar.

Venkatraman Ramakrishnan is a structural biologist at the Medical Research Council (MRC) Laboratory of Molecular Biology in Cambridge, England. He was born in 1952 in Chidambaram, Tamil Nadu. He did his B.Sc. Physics (1971) from Maharaja Sayaji Rao University of Baroda on a National Science Talent Scholarship from National Council of Educational Research and Training. He then moved to USA and did his Ph.D. in Physics from

Ohio University in 1976. Then he worked as a graduate student for two years studying Biology at University of California; while making a transition from theoretical Physics to Biology. As a post doctorate fellow at Yale University he worked on a *neutron scattering map of the small ribosomal subunit of E.coli.* He is also known for his study on *histone* and *chromatin* structures. He along with two other scientists from USA received the 2009 Nobel Prize in Chemistry for studies on the structure and function of the ribosome. Ramakrishnan has received many other prestigious awards— in 2007 Louis-Jeantet Prize for Medicine, the 2008 Heatley Medal of the British Biochemical Society and the 2009 Rolf Sammet Professorship at the University of Frankfurt. He received India's second highest civilian honour, the Padma Vibhushan, in 2010. He is a Fellow of the Royal Society, a member of European Molecular Biology Organisation (EMBO) and the US National Academy of Sciences and also a Fellow of Trinity College, Cambridge.

ACTIVITY 2.9

Identify the names of great women in the field of science and technology. Collect information about their contribution in science from library and internet. Give a power point presentation in the class.

ACTIVITY 2.10

Given equal opportunity, women are as par with men. Support this statement giving few examples.

ACTIVITY 2.11

Form a group of 4-5 student teachers. List some discoveries and inventions in science in the last ten years and discuss what significant role it has played in bringing about social change. Share your findings.

2.5 SUMMARY

In a nutshell, science is a social endeavour. It can be stated that an individual, society and country make great impact on science and vice versa. Science also makes great impact on the economic, social, psychological and cultural development of the society. Science is knowledge and knowledge is power. With power comes wisdom and liberation. Or, as sometimes happens, power can breed arrogance and tyranny. Science has the potential to be beneficial or harmful, emancipative or oppressive. History, particularly of twentieth century is full of examples of this dual role of science.

How do we ensure that science plays an emancipative role in the world? The key to this lies in a consensual approach to issues threatening human survival today. This is possible only through information, transparency, and a tolerance for multiple viewpoints. In a democratic political framework, the possible aberration and misuse of science can be checked by people themselves. **Science, tempered with wisdom is the surest and the only way to human welfare.** This conviction provides the basic rationale of science education.

EXERCISE

2.1 In a multicultural society today there is a greater need to inculcate strong social values in students. Express your opinion about it.

2.2 Do you think that everybody from her/his knowledge of science can contribute to the welfare and development of society? Supporting with example discuss the way one can do it.

2.3 Science has always responded to the needs of society. Comment.

2.4 Discuss the significance of physical science relating it to the surroundings around you.

2.5 Science helps in bringing all countries together. Justify this statement.

2.6 What is the role of a science teacher in making a socially responsible citizen of the country? Discuss.

2.7 Have discussion in small groups on how various discoveries in each of the following areas has affected our everyday life and society :
food; agriculture; medicines; electronics; communication; transport; energy sources. Share your information with other groups by giving a presentation in the class.

2.8 Do you think the job of a science teacher is to teach product and process of science without any social obligation? Conduct a panel discussion on this issue.

2.9 Search the website of UNESCO and review the contribution of this organisation in bringing peace and equity in society.

2.10 Describe the contribution of Dr. Homi Jehangir Bhabha to the indian atomic energy programme.

2.11 Highlight the important areas in science where our ancient Indian Scientists have contributed.

2.12 Arrange and organise a lecture of an eminent person in science in your college. Prepare a report of the lecture.

2.13 Given below are few names of women scientists. Search for more such names to update the list:

S.No.	Inventor	What was invented	Year
1.	Madam Curie	Polonium, Radium	1898
2.	Josephine Garies Cohran	Automatic dishwasher	1889
3.	Mary Anderson	Windshield Wiper	1903
4.	....	......	....
5.	....	......	....
6.	....	......	....
7.	....	......	....
8.	....	......	....
9.	....	......	....
10.	Bessie Nesmith	Liquid Paper	1951

Chapter 3

Aims of Learning Physical Science

3.1 INTRODUCTION

As a teacher or parent, we often hear children saying, 'Oh! Why should I study science?' Then we might ask ourselves, 'Why teach science?' The typical answer to this frequent question has been, 'Because science is all around us, so we need to know about it' or 'It is important to have an understanding of science for everyday life.' However, the children hardly find its relevance in their daily lives. Many students consider it too hard and monotonous to learn right from the early stages of education. This can be one of the reasons that we observe a declining trend in the enrolment of children opting science at higher levels.

It is a matter of concern and requires serious attention of the educational planners, implementers and other functionaries. To address the issue, firstly one needs to understand the aims and objectives of learning science. These guide them to frame and implement the educational policies towards the accomplishment of these aims. Since, teachers are the key agents to implement the curriculum, so they need to have a clear vision of the rationale, needs, aims and objectives of learning physical science to help them plan the stage and context specific teaching-learning strategies for its effective transaction. The origin of the aims follows essentially from the nature and structure of science and its interrelation to the society.

Let us discuss the vision of true science education. There are three factors involved here – the learner (child), the environment (physical, natural and social) around the learner and the object of learning (i.e., science). **We can regard good science education as one that is true to the child, true to life and true to science.** In the context of NCF-2005, 'true to child' means that the teaching-learning of science should be understandable to the child and be able to engage the child in meaningful and joyful learning. 'True to life' means that the science teaching-learning should relate to the environment of the child, prepare her for the world of work and promote the concerns for life and preservation of environment. 'True to science' means the science teaching-learning should convey significant aspects of science content at appropriate level and engage the child in learning the process of acquiring and validating scientific knowledge. The 'Position Paper on Teaching of Science, 2006' recognises the aims of science education as given below.

3.2 AIMS OF LEARNING SCIENCE

The science education is aimed for the learner to

- know the facts and principles of science and its applications, consistent with the stage of cognitive development;
- acquire the skills and understand the methods of processes that lead to generation and validation of scientific knowledge;
- develop a historical and developmental perspective of science and to enable her to view science as a continuing social enterprise;
- relate science education to environment (natural environment, artifacts and people), local as well as global and appreciate the issues at the interface of science, technology and society;
- acquire the requisite theoretical knowledge and practical technological skills to enter the world of work;
- nurture the natural curiosity, aesthetic sense and creativity in science and technology;
- imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment; and
- cultivate scientific temper– objectivity, scepticism, critical thinking and freedom from fear and prejudice.

The following discussion about these aims will enable you to understand and plan your teaching-learning in a child centred manner.

3.3 KNOWLEDGE AND UNDERSTANDING THROUGH SCIENCE

An important trait of humans is to wonder, observe and interact with the surroundings and look for the meaningful patterns and relations by making and using new tools and build conceptual models to understand this universe. This humans' endeavour has led to modern science which took thousands of years to get crystallised. So one can say that science leads to generation of ideas helping to make sense of observed facts that get accepted if they fit observations, but may be refuted until tested through evidence. These ideas represent a broad view and are generalised as the scientific principles that are true universally. According to Albert Einstein, **'science is a refinement of everyday thinking, a belief that becomes evident when one studies the work of scientists in their attempt to construct ideas that explain how nature works.'** The different aspects of science are viewed differently by scientists, philosophers and historians. When we speak about science, we do not refer to a particular aspect, because it is a broad-based discipline with many faces.

It is important for children to acquire the knowledge of science content, i.e., concepts and underlying principles as they provide a sound base to explore the unknown and build further knowledge, yet these cannot be passed to children directly. In addition, their understanding cannot be developed by rote learning. It can be done by providing children relevant and age appropriate learning opportunities that allow them to undergo experiential learning through exploration and interaction with their environment and construct their knowledge.

To help children understand the concept that *light cannot pass through all materials and when it does not, shadows are formed* – one way is to tell the definitions of transparent, translucent and opaque objects. Showing some of such objects is still better, but letting children observe and try different objects for the formation of shadows and then engaging them with those objects that form shadows under different conditions, such as distance from the source of light, direction of light, etc. can help them understand this concept better.

Creation of knowledge is crucial to children's learning. Their previous experiences are very important for it, as the experiences lead them to develop new ideas. Teachers need to collect such experiences of children to build further knowledge on their previous knowledge. For this they may engage the children in meaningful discussions through questioning and listening. Even children's drawings, concept maps also serve as good tools to acquire such information.

ACTIVITY 3.1

Discuss what aims can be achieved through teaching-learning of the concept, *'States of matter are interconvertible and can be changed by changing the temperature and pressure'* to class IX students.

3.4 NURTURING PROCESS SKILLS OF SCIENCE

Science is about asking questions and finding answers to them through scientific method and inquiry. The processes that scientists use in it are science process skills. Science is important to all young people for not only to acquire the knowledge associated with it, but also to imbibe its inquiry and process skills. As discussed in detail in the chapter on *Nature of Science* it is a process by which scientists collectively and over time endeavour to construct and accumulate reliable, consistent and objective representation of the world. These skills enable them to develop into adults who are able to take informed and responsible action while engaging and reflecting upon different ideas, opinions, beliefs or values. These are long lasting; thus, tend to be useful throughout each area of our lives. These skills involve the use of all the sense organs providing hands-on experiences for enjoyable and effective learning.

While we figure out many questions in our everyday experiences, we also use these skills.

However, often, the investigations are carried out in a routine fashion to let the children score in examination. If conducted properly, these activities not only raise the motivation but also develop interest and curiosity to learn and try things in different ways. In their strive to answer, 'what if,' children get actively involved in different processes such as observation, discussion, collecting information, manipulation, comparing, classification, improvisation, experimentation, critical thinking, logical reasoning, etc., thus enabling them to go through the processes of not only 'hands-on' but 'minds-on' as well. For example, children could be facilitated to observe natural phenomenon such as condensation, evaporation, rusting, seed germination, reflection, refraction, interference of light, electromagnetic induction, etc. Based on the observations and questions raised in the minds of children and asked by the teacher, problems could be identified and defined and hypothesis could be made. To test the hypothesis(es), experiments should be performed to validate or discard their hypothesis.

Science process skills refer to the following six actions without any particular order—observation, communication, classification, measurement, inference, and prediction. Applying these skills one can conduct objective investigation and reach at conclusions, based on the results. These are integrated together when scientists design and carry out experiments. All the six basic skills are important individually as well as when they are integrated. These can further be divided into different categories as illustrated through the following experiment performed by a student:

Sensing and identifying the problem: Water boils in the container faster, when the lid is placed over it than when it is not placed.

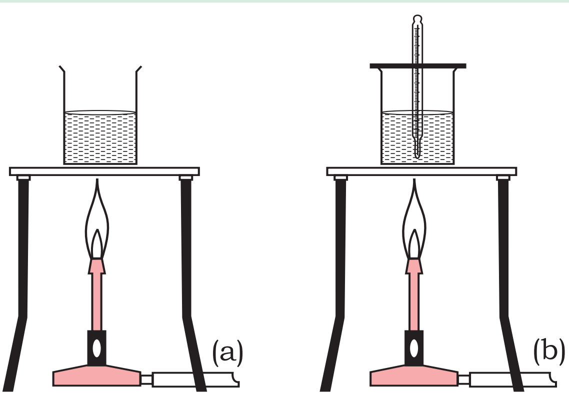


Fig. 3.1 *(a), (b) Boiling of water with the lid off and on*

Defining the problem: Does it have a higher temperature with the lid-on than the lid-off ?

Hypothesis: I think that water will boil at higher temperature with the lid-on as the lid prevents heat loss.

Testing hypothesis: Two sets of each of the following materials were required for testing the hypothesis— beaker, tripod, thermometer, wire gauze and Bunsen burner. A square/circular piece of cardboard was also taken to make the lid for the beaker. I used two beakers that were of same size and material. Then I put same amount of water in each beaker. The lid was placed on one beaker. When water started boiling I noted its temperature. The lid was kept off the other beaker. Temperature of water taken in the second beaker was noted down when it started boiling.

Collecting data : I did the investigation as described above. I pierced a hole in the cardboard lid to insert thermometer to take the temperature. I let the water boil for one minute before taking the observations.

Recording data

	Temperature
With lid	99.5 °C
Without lid	99 °C

Interpreting data: The two readings were almost same.

Drawing conclusion: I think that there is no difference in the temperature of boiling water with or without lid-on the beaker.

Making generalisation: I think fast boiling of a liquid does not mean high temperature of the liquid, that is why its boiling point does not change.

Further questions : Why do we cook food in closed vessels, rather than in the open ones? I read on the LPG slip that cooking with the lid on saves fuel. How does it save fuel? How the food gets cooked faster in the pressure cooker?

The problem may either be posed by the student or the teacher. It may also arise as an idea during discussion. The teacher needs not provide the whole plan to carry out the investigation, but should involve children to evolve the plan through discussion. She may help children to work in groups to carry out the investigation. Some children might be trying to heat water in beakers of different sizes/materials. Some might use unequal amount of water in the beakers. There could be variations in taking the temperatures, readings of the thermometer, etc. Through questioning, discussion and sharing the work mutually and with the whole class, the children may be trained in this approach over a period. This can help them develop the skills of scientific process and inquiry.

ACTIVITY 3.2

Discuss how does the teaching-learning of science helps enrich the process skills? Identify some situations in everyday life where these skills can be enriched.

ACTIVITY 3.3

Design learning situations in physical science for the students of upper primary, secondary and higher secondary stage and identify the process skills associated with each step of learning situation. Give a presentation on it in the class.

The teacher has an important role to play in providing children with experiences, which can help nurture these skills. She may consider the following points:

- Children should be given various opportunities to develop process skills of science. Action provides the practical basis for thinking, e.g., simply telling what it means to observe, investigate, experiment and interpret have no meaning until given an opportunity to try these.
- Opportunities for discussion in small or large groups and in the whole class may be provided. These allow children to listen to others, explain, argue, express and share their ideas, thus involving them in thinking what they have done, relating to the evidence and considering multiple ways of approaching a problem.
- To help children develop process skills, it is important for the teacher to know how children are using those skills. The teacher can observe their work and listen to their discussions to pick up information on how children have collected and used the evidence.
- The children need to realise the area of the skills in which they need improvement. For this, they may be allowed to discuss their investigation and critically reflect on it. The teacher can encourage them to try alternative courses of action for improvement.
- For increasing accuracy in acquisition of some skills, there may be a need for introducing new techniques and tools. For example, for measurement of different quantities children require various instruments such as balance, vernier calipers, screw gauge, thermometers, graphs, etc.

3.5 DEVELOPMENT OF SCIENTIFIC ATTITUDE AND SCIENTIFIC TEMPER

Science learning and development of scientific attitudes and temper are complementary to one another. Thus, it is imperative for science teachers and educators to understand the meaning, significance and process of their development.

Scientific attitude: Scientific attitude is a composite of a number of mental processes or tendencies to react consistently in certain ways to a novel or problematic situation. These include accuracy, intellectual honesty, open-mindedness, respect for evidence, scepticism, suspended judgement, critical thinking, perseverance and looking at true cause and effect relationship. Scientists, because of their thirst for knowledge become perpetual learners. They are constantly curious and continually seeking knowledge by inquiring. This in turn nurtures the trait of scientific attitude.

Scientific temper: It is an attitude of mind which calls for a particular outlook and pattern of behaviour through logical thinking, discussion, argument and analysis to avoid bias and preconceived notions. It is neither knowledge of facts nor rationalism, but promotes knowledge and rational thinking.

Scientific attitudes and scientific temper have many overlaps in their meanings. Therefore, we are dealing both of these together. We can say that development of attributes such as respect for evidence, open-mindedness, truthfulness, critical and logical thinking, scepticism, objectivity, perseverance, curiosity, creativity and inventiveness, sensitivity to living and non-living and cooperation with others through exploration of the world around leads to inculcation of scientific attitude and scientific temper. These qualities affect the willingness of pupils to take part in the activities, respond to persons, objects, situations or events in rational manner. These may not be placed in a sequential order and looked upon as water tight compartments. Also their development is not spontaneous. These qualities can be nurtured over a period of time through the process relevant learning situations that require creating an open classroom environment encouraging children to perform activities and experiments and reading scientific literature, freely interacting with their surroundings and asking questions.

The following discussions will give you an idea about what each aspect mentioned above means and how it can be developed and nurtured during the teaching-learning process for developing scientific attitude and scientific temper among students.

3.5.1 Respect for evidence

There should not be any haste in making and evaluating a judgement in science. It should be based on suitable evidences. While developing skills of collecting evidences for verifying and testing ideas, the students must be trained to confront ideas with evidences. If ideas conflict with evidences, students should be encouraged to check again and collect more evidences for reaching a conclusion. They should be flexible and willing to change their ideas where there are convincing evidences to the contrary.

John Dalton's atomic theory was backed by experimental evidences. It was based on the laws of chemical combination. He was not the first to propose that the atom was the smallest particle of matter, but he was the first to use experimental evidences to support his theory.

3.5.2 Open-mindedness

For true learning in science, it is important not to have a set mind with preconceived notions. An open-minded person is one who can modify plans or discard hypotheses, if necessary and accepts a new explanation, model or paradigm, because it explains the evidence better, is simpler, has few inconsistencies or covers more data. An open-minded person evaluates all reasonable inferences, remains open to alternative interpretations, accepts new priorities in response to a re-evaluation of the evidence or re-assessment of the existing ideas and does not reject unpopular views outrightly. He structures and restructures his ideas as he progress in learning. In short, it is to learn that '*my way is not the only way*.'

The teachers can help students acquire this through activities and experiments, frequent collaborative work and discussions in which each child must be given an opportunity to express her viewpoint. Others can reflect on it in socially acceptable manner.

ACTIVITY 3.4

Find out some examples of the great scientists that reflect the importance of respect of evidence and open-mindedness in physical science.

3.5.3 Truthfulness in reporting observations

We all know that how important it is to report the authentic observations in the experiments to arrive at the conclusion. In scientific procedure, observations in an experiment are repeated and verified before arriving at conclusion. Teachers should encourage honesty in reporting the result of the experiments among students. She should create a fear free environment in which students do not feel scared if the results deviate markedly. If need arises, she should work with the students to help them find out the reasons for the discrepancies and guide them, so that they don't manipulate the results.

While performing experiment on the laws of reflection, if a student does not find equality between angle of incidence and angle of reflection, the teacher should help the student to focus more on the precautions to be taken for the experiment. If the variation is large, the student can be asked to repeat the procedure to find out the sources of error and help her arrive at the conclusion.

ACTIVITY 3.5

Recall any experience of your student life where you could/did not get the expected result of experiment conducted by you. What do you think would have enabled you to get the expected results? Think, pair and share with your classmates in the class.

3.5.4 Critical thinking

In science, critical thinking increases science learning potentials. It requires deliberate review of the way in which activities are carried out, the ideas emerges and the way these can be improved. It is the ability to analyse information and experiences in an objective manner. Reflecting on the processes of thinking does not come readily to young children as it involves abstract thinking as well. Teachers can facilitate this by engaging the children in discussions through activities. Following actions should be emphasised for the development of this attribute.

- Willingness to review the work done for its further improvement.
- Considering alternative ways.
- Identifying the aspects that are for and against the way adopted.
- Reflecting on the previous work to identify the mistakes and avoid those in the next.
- Focusing on relevant scientific facts; and
- Asking open-ended questions such as involving verbs '*your point of view*.., *what do you think about it* (say a phenomena)..' '*Assume that*'.., '*support/justify/interpret*', etc.

3.5.5 Logical thinking

The process of linkage of the past experiences in terms of cause and effect relationship on a model of set rules, i.e. thinking with reasoning is known as logical thinking. Children should be helped to reason out consistently before arriving at conclusion. Scientific temper is the refined logical thinking. The refinement in logical thinking can be brought in by taking observation, quantifying the observation to increase the resolution of our observation and organising the information gathered from observation. Organising includes recording of the important information, classifying and looking for pattern. On the basis of pattern or no pattern hypothesis is made (why and how) and verified to know whether explanation holds good in other situations.

One of the reasons why Gregor Mendel could discover the principles of heredity when others failed, was his habits of following logical experiment and careful and accurate record keeping.

ACTIVITY 3.6

Discuss with an example how learning of physical science helps in developing logical thinking.

3.5.6 Scepticism

Scepticism is questioning the accepted beliefs, ideas or facts in the society on the basis of scientific investigations. For instance, superstitions amongst the people are developed due to ignorance and customs that people follow due to fear and mythical explanations of the events. Science teaching-learning can help students in questioning such beliefs. For example, the ancient people believed that the earth was balanced on the horns of a bull and when the bull shifts it from one horn to the other, an earthquake occurs. This belief proved wrong only through science when the occurrence of the earthquakes were established as the tremors caused by the disturbances deep inside the earth. A lot of superstitions still prevails in society and even some educated people continue to follow them, sometimes out of fear of the unknown. You can look objectively (weigh the evidence) at the practice of throwing away all food items after solar or lunar eclipse. There are various other examples of superstitious beliefs which have no scientific basis like sneezing at the time of stepping out of your house or a cat crossing your way are bad omens, etc. Before believing in such things and falling prey to such unscrupulous practices, children need to be taught to weigh properly the scientific evidences in favour or against such beliefs. 'Summer is caused by the earth being closer to the sun,' 'lightning never occurs at the same place twice,' 'mother is responsible for the sex of a child' are some of the myths to be busted through teaching-learning of science. Myths and superstitions should be discarded by making and evaluating judgement on the basis of evidences. Scientists must constantly guard against their own tendency to be dogmatic and should not accept things blindly without questioning. The teachers need to organise planned debates on such issues and encourage children to participate in the discussions, thus, sensitising them gradually against the causes by promoting rational and critical thinking.

ACTIVITY 3.7

Find out some superstitious practices prevailing in society and suggest how would you tackle with such issues with your students in the classroom.

3.5.7 Objectivity

Objectivity is looking at the things without any preconceived notions, biases, prejudices or discrimination. It can be developed by understanding the importance and use of evidence. This would also help in developing respect for evidence. **Learners should be open to others' ideas and should respect others' point of view, but they should accept the ideas only after testing and verification or with sufficient evidences.** This also requires a change in our traditional authoritarian attitude. While developing skills of collecting evidence, verifying and testing their ideas, following points should be emphasised.

- Respect others' ideas or point of view, based on sound logic.
- Confront your ideas with evidences. If ideas conflict with evidences, collect more evidences before reaching a conclusion.
- Treat all ideas and statements as provisional.
- Be flexible and willing to change your own ideas if they are not consistent with the evidences. Unless there is such a tendency, the new experiences are sure to conflict with existing ideas.

Children can be made open towards this quality by eliciting examples of how other people's ideas and those of the great scientists changed.

3.5.8 Perseverance

It is expected that the students are given opportunities to work repeatedly to arrive at conclusion which is scientifically valid. The teachers may elaborate on this aspect through narration of the efforts of scientists such as Marie Curie, Howard G. Rogers and Thomas Alva Edison. For example, the electric bulb in all probability had been invented much earlier than Edison did this work. Edison tried thousands of materials for the filament before he hit upon just the right one that made the bulb long-lasting and practical. Such was the perseverance of Edison. He stated once that he did not fail 1999 times when the bulb was not made, but he learnt how through these 1999 ways bulb could not be prepared. Rogers, a chemist spent 15 years experimenting with over 5000 different chemical compounds before inventing a new chemical molecule which represented a big breakthrough in developing a photograph and gave birth to polaroid colour film. History is full of such successes stemming from continuous failure. The teachers should try to address the myths about science and scientists by preventing any prejudices to be passed on the students. The mistaken projections of science such as 'it is devastating and damaging effect on the environment'; 'scientists are absent minded persons narrowly concerned with their work;' 'scientific knowledge can only be discovered by trained scientists, need to be avoided.' **Scientists' qualities of critical and logical thinking, open-mindedness, hard work, perseverance, love for the search of knowledge should be highlighted.** A science teacher needs to provide children experiences of a number of scientific activities as base for a thorough understanding of science and developing scientific attitude and temper.

Project 3.1

Collect some examples of great scientist's contributions to society that you think can be narrated to your students to develop the qualities of objectivity and preseverance.

3.6 NURTURING THE NATURAL CURIOSITY, CREATIVITY AND AESTHETIC SENSE

3.6.1 Nurturing curiosity

Once Rina went to market with her friend Mary. There she saw children enjoying coloured ice lolly *(chuski)*. She also asked for an orange lolly and observed keenly while the vendor was preparing it. The vendor pressed the crushed ice to make the ice ball and poured coloured syrup to make it tasty. She became curious to know how does the crushed ice take the shape of a ball when pressed and asked her friend about it.

Mary replied, "I think it happens due to lowering of melting point of ice on increasing the pressure. When ice crushes are squeezed, pressure increases and ice at their contacting surface melts. On relieving the pressure, melting point rises back to normal and layers of water between ice crushes freeze again. Do you remember we studied this in the Chapter on *Thermal Properties of Matter?*"

"Yes, now I can recall. We had performed an activity by putting a metal wire over an ice slab and hanging two heavy weights at the ends of the wire. The wire had passed through the slab and to our surprise, the ice slab did not split," Rina said.

Mary added,"Our teacher has very well explained that this happens because just below the wire, ice melts at lower temperature due to increase in pressure. The water above the moving wire freezes again as pressure is removed. We call this *regelation* (Fig. 3.2). I think the same is happening here."

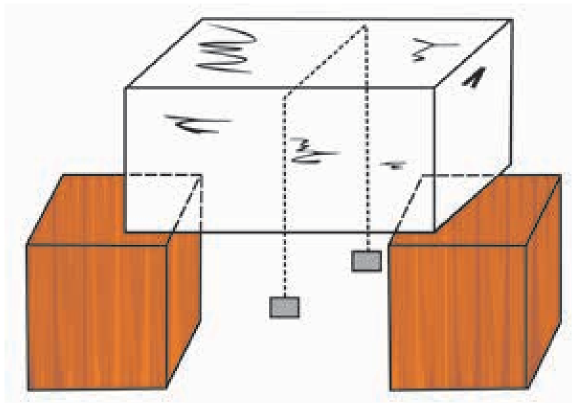
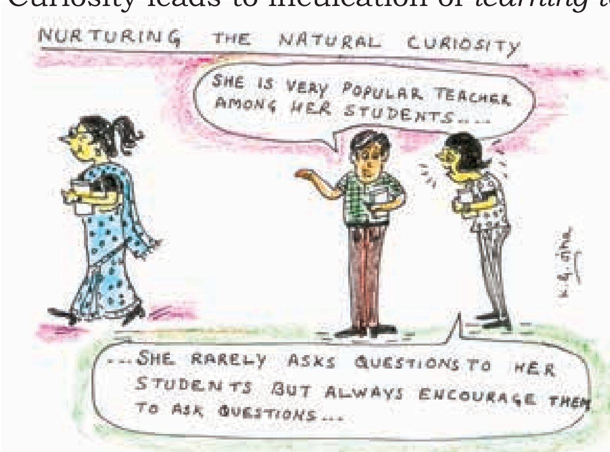


Fig. 3.2 *Regelation of ice*

"Tomorrow we will discuss about our explanation with our teacher. She always encourages us to ask questions and clarifies our doubts and concepts," Rina further added.

Thus curiosity led to questions in her mind like why, what and how. When students ask such questions, the teacher should not discourage them. She should facilitate them to find answer using scientific principles.

Aristotle had once made the statement, *All men by nature desire to know.* Children learn more due to their natural curiosity. They should be made curious by developing interest in science by observing, asking question and experimenting. Science is nothing but all that happens around us. Students come across many questions out of curiosity. Curiosity leads to inculcation of *learning to learn* aspect of education.



Curiosity can be generated in the learners by taking them to science centres; providing opportunities to work on science projects and to read scientific literature; facilitating interaction with persons having scientific attitude; encouraging to participate in science exhibition and science quiz, etc. Science activities can be designed to encompass several factors making up curiosity. **Curiosity gets aroused as a result of doubt, perplexity, contradiction, cognitive conflict, ambiguity, lack of clarity, etc. A teacher needs to create suitable learning situations for this.** Science teacher must take advantage of natural curiosity of children by engaging them in the exploration of the ideas of the concept being transacted through scientific processes and inquiry. For nurturing curiosity, the teacher should create learner-friendly classroom environment where they are free to interact with the teacher and the peer group. It is generally observed that classroom conversation is dominated by few vocal students. Some shy students do not ask any question. The teacher should try to involve the whole class in the teaching-learning process by encouraging the students to ask questions and get involved in activities, experiments and projects.

ACTIVITY 3.8

Choose any concept of physical science and design a learning situation with suitable questions to raise the curiosity of your students for it.

3.6.2 Nurturing creativity

Science teacher must take advantage of natural curiosity of children

Creative thinking is a novel or innovative way of seeing or doing things. It has four components—fluency (ability to express oneself readily and effortlessly), flexibility (shifting perspective after getting convinced easily), originality (conceiving of something new) and elaborating (building on other ideas). It is also referred to as thinking 'out of box'. Creative thinking enables a learner to explore available alternatives and consequences of actions or non-actions and contributes to decision-making and problem solving.

Creativity has been defined in different ways. It is the production of relevant and novel product and process. Also, it involves classification and assessment of different components of the problem or delineation, manipulation and linkage of ideas in a novel manner to solve a problem, or to deal with an idea or to confirm a conclusion.

For nurturing creativity the teacher can follow a variety of activities such as questioning, gathering relevant information and analysing and processing it to solve problem, looking for a number of ways to approaching a problem, thinking aloud, enacting a play/drama, writing poem, constructing models, conducting open-ended experiments, etc. These activities can bring out the hidden talent of the learner. Children should not be stopped to ask questions saying, *'your question is irrelevant or out of syllabus.'*

A discussion on natural satellites was going on in Class XI when a student asked, "what would happen if there is no moon in the sky?" Rohit the teacher directed this thought provoking question to the whole class. Students came up with a number of answers— some relevant, some irrelevant. Rohit listened, called a student to write all answers on the blackboard without labelling them as right or wrong. Some of the responses were, *"our earth would spin faster;" "days and night would be shorter," "we would get less time at school/to watch TV/to sleep;" "there will be complete darkness in the night;" "whom with the poets would compare the beauty;" "wind would blow faster;" "life would not have existed on the earth;" "centre of mass of the earth would have been different;"* and *"the axis of rotation of the earth would be different."* Later Rohit discussed with them the probable answers and asked students to collect more information related to the question and justify their answers through the group project work in the class.

Creativity is doing or seeing the things differently. It cannot be taught, but developed in children by using planned strategies and techniques. Emphasis should be given on providing appropriate concrete experiences which nurture creative traits in a learner, viz. curiosity, ability to fantasise, playfulness, as well as cooperative and helpful attitudes in teaching-learning of science. Systematic efforts should be made to enhance quantity, variety and originality of ideas amongst children.

The teacher plays an important role for nurturing creativity in learners. **From pedagogical perspective of physical science, inquiry and activity oriented, process based teaching-learning can facilitate in nurturing creativity.** Therefore, the role of the teacher should be to–

- assist students in developing models of inquiry and discovery;
- guide students in the use of multidisciplinary approach;
- recognise and appreciate creative ideas and products of students;
- provide rich variety of learning experiences to students;
- encourage students to frame questions and browse variety of reading materials; and
- express to the students that their ideas have value.

Teacher should be respectful to unusual questions and imaginative unusual ideas of learners. Occasionally, provide opportunities to them to do tasks without any fear of evaluation. Let the learners evaluate the task on their own without pointing it as right or wrong. Do not tell the results of an experiment in advance. Help them to reach the conclusion.

A creative child thinks differently, expresses unending curiosity and possesses divergent thinking ability. She wonders what makes things work. She is always a keen observer who ponders over the outcome of an event of phenomena and seeks information. She has original, divergent, independent, fearless and intuitive thinking and welcomes new ideas. She likes to ask thought-provoking questions rather than fact seeking or memory type questions. Teachers should identify these traits and provide a variety of learning experiences of inquiry and discovery of science to nurture creativity.

Creativity is not related to any particular subject area. Science education provides opportunities to a person to create something new for the society and the nation. It has a wide scope of fostering and encouraging creativity.

3.6.3 Nurturing aesthetic sense

Aesthetics deals with the creation and appreciation of beauty that gives us happiness. Harmony, order and pattern are some of the criteria which define beauty. A learner of science is also concerned with them. She gets motivated to see some patterns in the properties of substances and other things in her surroundings. She appreciates her creation and derives joy when finds that a particular toy or a gadget works on same scientific principle that she has already learnt.

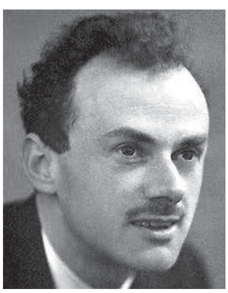
A scientist, like an artist, is in search of harmony. The harmony of nature and its experience, direct or indirect, is believed to be expressible in different ways. In science the harmonious character of nature is visible in laws and theories in their proclaimed scope of universality. Theory of gravitation is a prime example of universality. Since science is a body of knowledge acquired through the application of the scientific method and process, this knowledge at several stages has some pattern, order and harmony and universal acceptability. Therefore, studying science nurtures aesthetic sense amongst children. Learners should be encouraged to explore harmony, pattern and order in properties of substances and various natural phenomena and principles of science to infuse aesthetic sense among them. For example, during learning of the properties of different oxidation states of vanadium element we see a definite pattern and beauty in the change of colour from one oxidation state to another.

The chapter 'The Solid State' provides a wonderful opportunity to talk about the arrangement and array of lattice points thus helping to inculcate this skill among students. The teacher may encourage students to look out, how inspired by this beauty in nature we design buildings and structures. This not only removes the monotony of the class, but also helps connect the classroom teaching-learning to life experiences.

For nurturing aesthetic sense through science teaching learning, the teacher may encourage students to consider the following steps:

- Observe keenly while doing any work. For example, observing the flowers while walking in the garden one can appreciate their colour and wonders why the flower is of that particular colour. Observe, analyse and reject what is not scientific.
- One should be conscious of one's inner being.
- Learn to be generous. One should develop the sense of sacrifice and self-righteousness.
- Choose words carefully. Refrain from sarcastic remarks and taunting words to anyone and gossiping.

Nobel Laureate Physicist Dirac also emphasised the need to appreciate beauty in Physics and credits a sense of beauty for his remarkable insight into arriving his famous Dirac's equation for which he received the Nobel Prize. He claimed that a 'keen sense of beauty' enabled him to discover the wave function for the electron.



"I think there is a moral to this story, namely that it is more important to have beauty in one's equations than to have them fit experiment.... It seems that if one is working from the point of view of getting beauty in one's equations, and if one has really a sound insight, one is on a sure line of progress. If there is not complete agreement between the result of one's work and experiment, one should not allow oneself to be too discouraged, because the discrepancy may well be due to minor features that are not properly taken into account and that will get cleared up with further developments of the theory..."

Paul A. M. Dirac (1902–1984) was an English theoretical physicist. He formulated the Dirac equation which describes the behaviour of fermions and implied the existence of a new form of matter *antimatter*. Dirac shared the Nobel Prize for physics in 1933 with Erwin Schrodinger, for the discovery of new productive forms of atomic theory. He held the Lucasian Chair of Mathematics at the University of Cambridge. He served as Professor of Physics at Florida State University for fourteen years.

3.7 RELATING PHYSICAL SCIENCE EDUCATION TO NATURAL AND SOCIAL ENVIRONMENT, TECHNOLOGY AND SOCIETY

3.7.1 Environment

Relating science education with the environment of a child has been the prime concern of educationists. The environment of a child includes natural and social environment, artifacts and people.

In science we learn about the environmental phenomena of both natural and man-made interventions affecting the environment. We can say that science education is mainly of the environment and for the environment. Therefore, every effort should be made to integrate science with learning the environment. The science curriculum should address issues and concerns related to environment such as climate change, acid rain, growth of water eutrophication and various types of pollution, etc. through teaching-learning of science at all stages.

Students will be attracted towards science when they realise its significance to society and relevance to their lives. Science teacher should aim to enlighten the young minds with the wonders of science. Students should be made to realise the significance of discoveries, inventions and principles of physical science through their everyday experiences. They should be engaged to construct the knowledge of physical science through an interdisciplinary approach appreciating its relation and impact on the social and natural environment. They can recognise the importance of science/physics/chemistry by doing activities related to their everyday life.

Current issues and events in science like new technological innovations, scientific discoveries, industrial accidents can be examined through social, economic and ethical perspectives to help students in relating these issues with one another and explore their areas of interests.

The significance of chemistry to society can be highlighted by discussing the chemical components used in products that have altered agriculture, food, health, medicine, electronics, transportation, technology and the natural environment. We use chemical fertilisers, such as urea in agriculture. We also use fungicides, pesticides and herbicides for better yield and crop protection. In medicine anticoagulants, vaccines, hormones, antibiotics, anaesthetics, analgesics are prepared using different chemical compounds. In vehicles we use fuel and fuel additives, alloys, paints, plastics and refrigerants. One can explore such products in electronic equipments and foods.

When we enter our home we see many products like plastics, adhesives, wall paints, cosmetics, dyes, disinfectants, which are the precious gifts of chemistry.

Similarly importance of physics to different areas like agriculture, transportation, food, medicine, household products, electronics, defence, communication, engineering, manufacturing and environment, and social science should be emphasised. To understand its relevance to home economics, one can think what happens to the electricity bill if solar cooker, solar heater, solar lanterns and CFL (Compact Fluorescent Lamp) are used. Activities, such as use of pressure cooker and greasing the moving parts of a vehicle reduce energy loss.

Project 3.2

This project can be carried out as a group work. Study/Investigate the impact of chemistry and physics or science as a whole on different aspects of daily life through experiments, activities, discussion, debate, drama and project work. The groups can share their information and interact with the other groups through discussion, presentation, poster presentation or internet or through any other mode.

ACTIVITY 3.9

Read the following news item and organise a debate in your class to discuss on the use of nuclear energy for the development of society.

April 26, 2011

Public split on nuclear energy

Just over a month after the massive earthquake and tsunami that struck north-eastern Japan, a nuclear power plant in Fukushima was crippled. The pros and cons of nuclear energy have never been put up to nationwide public debate via the media. The public is divided on whether nuclear power plants should be preserved and expanded, or scaled back and abolished. According to a Mainichi public opinion poll published in the April 18 morning issue, 40 percent of respondents said, that the nation's dependence on nuclear power was unavoidable, while 41 percent said, "the number of nuclear power plants should be cut back," and 13 percent said, "such plants should be abolished altogether." Japan has been split in two, into a Japan whose people seek continued economic growth and prosperity grounded in nuclear dependence, and another Japan whose people are convinced of the need to depart from that model once and for all.

It is the government's role to bridge that divide and coordinate diverging views, but it lacks the knowledge and wisdom needed for a debate that cuts to the crux of national policy. Understandably, the government is currently overwhelmed by the pressing task of bringing the Fukushima plant under control and rebuilding the country's quake, and tsunami ravaged north-east, but that does not mean we can ignore the possibility that another massive earthquake will hit Japan, in the Tokyo metropolitan area or the Tokai region. Plus, is there any guarantee that such a tremor will be a magnitude 7 or thereabouts, as the Central disaster Prevention Council has predicted?

Today, there are 54 nuclear reactors in Japan, accounting for 30 percent of the country's total energy supply. Is the government's plan to boost the nation's dependence on nuclear energy to 50 percent by adding 14 more reactors by 2030 a sound one? Let us hope for some bold debate. (By Takao Yamada, Expert Senior Writer)

The Mainichi Daily News, Japan, April 26, 2011

3.7.2 Technology

Science and technology are linked to each other. Discoveries in science have paved the way for the evolution of new technologies. At the same time technology has been instrumental in the development of science.

The Development of microscope by the Dutch tradesman, A.V. Leeuwenhoek brought about frantic activity that intertwined optical principles with astronomical and biological understanding and it led to further technological developments of the telescope and microscope. Gains in the theoretical knowledge about the telescope led to significant gains in the understanding of its design and optical properties. These have contributed to the development of very large telescopes which revolutionised our understanding of universe.

Thus, science influences technology by providing knowledge and methodology, but on the other hand technology also influences science by providing equipments. This shows interdependence of science and technology.

In science we inquire how a natural phenomenon occurs, while in technology we deal with how the scientific processes can be used for human welfare. Thus, when we bring science and technology together, we bring knowledge and action together. Technology as a discipline has its own autonomy and should not be regarded as a mere extension of science. The indigenous technological knowledge that existed around the world is in danger of extinction due to the sweeping dominance of modern technology.

Technology component of science curriculum could include design and fabrication of simple models, practical knowledge about common mechanical and electrical devices and local specific technologies.

Science principles may remain unchanged, however it can lead to new technologies as the time progresses.

ACTIVITY 3.10

Prepare a list of some significant inventions and discoveries and look out the corresponding scientific principles that made them possible.

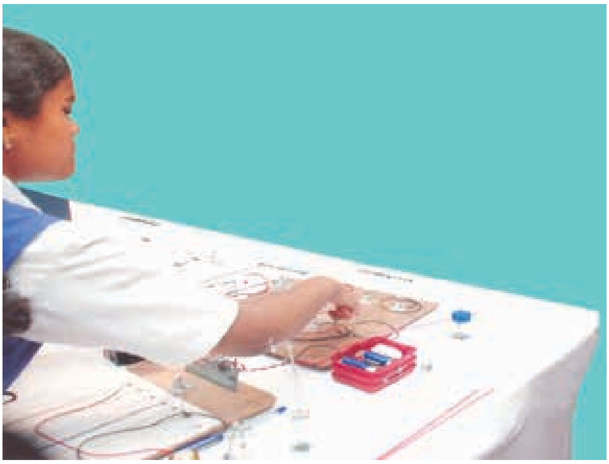
3.7.3 Society

We have discussed in Chapter 2, how widespread applications of science and technology have led to the remarkable improvement in the quality of human life. It has provided the humankind with comfort and leisure on the one hand and equipped it with the skills needed for problem solving and decision-making on the other hand. It has changed the outlook of the individual, the group or the society on different beliefs, myths, taboos and superstitions. People have started working with logical thinking, objectivity and open-mindedness. Modern society recognises the diversity in social and political thinking and believes in coexistence. It has started thinking for the welfare of our future generations and talks about sustainable development. Society also shows its concerns for use of scientific knowledge for peace.

3.8 IMBIBING THE VALUES THROUGH SCIENCE TEACHING

The Delor's commission (1996) of UNESCO in its report entitled 'Learning : the Treasure Within' advocates the need to cultivate core universal values like human rights, sense of social responsibility, social equity, democratic participation, tolerance, cooperative spirit, creativity, environmental sensitivity, peace, love, truth, non-violence, etc. within the learner. **Education for human values is an important area that needs to be promoted at all stages of education.** Values are abstract and multi-dimensional and present an ideal for the members of the society to shape their personalities. Science offers many opportunities for value inculcation. These cannot be imposed, but need to be part and parcel of the teaching-learning process. There is no need to have a separate period for value education. Teachers can integrate values during teaching-learning of different subjects like science, language, social studies, mathematics, arts, crafts, etc. For example, during the teaching-learning of the concepts such as the *States of matter* you can discuss the values of coordination, unity and staying together based on how the bonding and forces of attraction vary between the molecules of the three states. Similarly, while discussing friction one can talk about how reducing friction increases the efficiency of the machine by preventing energy dissipation. In the same way, quarrelling leads to wastage of energy and time. Thus, science offers many opportunities of value inculcation for students. The following values can be developed through teaching-learning of science:

- **Patience:** In waiting for results of experiments.
- **Perseverance:** In doing the experiments again and again until result is achieved.
- **Cooperation:** Willingness to work with others, and share equipments and materials.
- **Honesty:** In gathering and recording data.
- **Integrity:** Whose work can be relied upon.
- **Concern for life:** Caring for health and hygiene and others.
- **Preservation of environment:** Keeping surroundings clean, caring for plants and animals, switching off the light when not in use.



Activities and experiments allow students to observe, verify and inquire

The values through science can be imbibed by following strategies.

Activities and experiments: Scientific activities and experiments allow one to observe, verify and inquire. Teacher should make it a point to interact with each student individually and by questioning with the suitable use of *why, how, when, what,* etc. to orient their thought process towards critical observations, logical thinking, cause and effect relationship and correlate their present experiences with their previous learning. All work needs to be done with full honesty and integrity. In a group work, cooperation from all students should be ensured. The activities should also nurture the concern to take care of our environment. All activities in science education should be finely interwoven with the values needed for the betterment of mankind through its different processes.

Drawing analogies of concepts: We can take some examples of chemical bonding in which a covalent bond is formed by sharing of electrons. It can be shown that with the cooperation with each other a strong relationship is developed.

Narrating the biography of great scientists: The narration of biographies of great scientists inspire the students to imbibe scientific values.

Teaching-learning the content of Science: Science content is based on order and pattern. There are many concepts in science like cohesion, attraction, gravitation, etc. which give us opportunity to imbibe values. The human values are hidden in science concepts which are to be identified and practised by the students.

Working as role models: It is important that teacher plays a role model to her students. The environment of school should remain charged with scientific, democratic, social and moral values.

3.9 DEVELOPMENT OF PROBLEM SOLVING SKILLS

Problem solving means that an individual has learned the skills and acquired relevant information necessary to solve problems that are not only curricular, but also related to everyday life.

Various skills required for problem solving can be enhanced by providing opportunities to students to ask questions, think aloud, look for alternative explanations and procedures, isolate and control variables, keep record, apply reasoning and analogy, make models, and apply process skills in teaching-learning of science. Students can explore such potentiality while working on the problem. They feel a sense of achievement on getting success and develop self-confidence.

In order to provide opportunities of problem solving we need to inculcate the following abilities among the learners:

- Flexible and divergent thinking;
- Decision-making and generating self-confidence;
- Accepting/rejecting hypothesis;
- Correlating between various quantities/phenomena;
- Checking the validity of results;
- Expressing the task in terms of goals;
- Searching for innovative practices;

- Creating new challenges for life; and
- Developing positive and cooperative attitude.

To solve problems in science, students must acquire what cognitive psychologists call *declarative knowledge* which consists of the body of knowledge and facts needed to work in science. Simply acquiring knowledge of science is not sufficient. One must organise this knowledge in such a way that can be retrieved easily to solve problems. Simultaneously, with acquiring and organising declarative knowledge, one must also acquire *procedural knowledge* (knowledge of processes) which are procedures and heuristics that can be applied to solve problems. For example, the knowledge that an ammeter is a current measuring device is declarative knowledge. How it can be used in an electric circuit to measure current and why it is used in series in the circuit is procedural knowledge. Declarative and procedural knowledge may not be mutually transferable automatically. To address this problem teacher needs to emphasise on learning inquiry and process skills of science.

Everyday students take milk or tea in the cup/glass/vessel made up of different materials. Problem may be raised as— equal quantity of tea is to be served to six children in six vessels of equal capacity, but made up of different materials. Cup of which material will you select, so that your fingers will not burn? Will the tea acquire same temperature after equal interval of time? What are the factors on which rate of cooling of tea will depend? Would it depend on the thickness of the vessel? Would it depend on the density of material of the vessel also? Many students might not have thought over this problem. However, when the situation is created and questions are posed, students start thinking that problem exists.

ACTIVITY 3.11

Read the topic on *Physical and chemical change/Electric current and its effects* (or a topic of your choice) at upper primary stage. How can you develop problem solving situations to transact various concepts on the above topic? Think, pair and share with your friends.

3.10 ROLE OF A SCIENCE TEACHER

Science teachers may consider following points to engage students in problem solving activities.

- Help students to recognise problems by presenting appropriate situations and asking probing questions.
- Encourage students to pose problem in the form of queries/ questions.

- Give chance to students to devise their own thinking strategies and avoid giving solution to problems right in the beginning.
- Provide suggestive (not prescriptive) hints to students so as to raise their level of performance.
- Interact in a friendly manner with students during teaching-learning process to get an idea of their thinking process and provide help if need be.
- Encourage peer interactions.
- Provide opportunity to students to acquire procedural knowledge i.e. instead of stressing on the term/formula, let the students also learn the logic of the formula used.
- Help students to develop the habit of using different resources, i.e. textbook, reference books, class notes, periodicals, magazines, internet, etc.
- Present learning tasks in a challenging way.
- Invite problems and pose problems in a variety of learning activities such as doing activities and experiments, field experiences, interacting with the experts of the subjects, reading and viewing content through different media.
- Design innovative, conceptual, numerical, graphical and diagrammatic types of problems.
- Design problems to generate cognitive conflict.
- Involve every learner in the teaching-learning process.
- Give adequate time to students to collect enough data relevant to the problem and revise or modify their hypothesis.
- While checking answer sheets of students discuss your observation and provide constructive feedback.
- Discussion and argumentation should be encouraged in science classes.
- Be open-minded.

3.11 SUMMARY

It is important for a physical science teacher to see the connections among various aspects of the aims of learning science with the classroom practices and realise that these aims are long-term goal and their achievement requires a sustained and continuous effort. These aims cannot be achieved in isolation, but through the transaction of the concepts of physical science. Hence, **physical science teacher should have a sound understanding of the subject. This is the very first requirement for the acquisition of aims of teaching-learning physical science.**

You are now suggested to revisit the aims of learning science given in Section 3.2 of this chapter in the light of the above discussion on the role of teacher. You have to keep them in mind while planning your lesson about which we shall study in Chapter 12 *Planning for Teaching-Learning of Physical Science*. To be brief, we can quote Mahatma Gandhi: **"True education is that which draws out and stimulates the spiritual, intellectual and physical faculties of the children."** Implicit in the aim is the belief (that we share) that education has the potential to transform individuals and societies.

EXERCISE

3.1 In what way the aims of learning physical sciences differ from those in other disciplines? Illustrate using one example.

3.2 How do the knowledge of aims help a science teacher in teaching-learning of science?

3.3 What qualities can be nurtured in learners to develop scientific attitude in them? Explain.

3.4 How do you think creativity, curiosity and aesthetic sense can be developed in learners? Illustrate with examples.

3.5 Discuss how physical science education is related to natural science and social environment, technology and activity with the help of examples.

3.6 What sustained effort a teacher of physical science should make to realise various aims of learning? Discuss.

3.7 'Values cannot be taught, but caught.' Do you agree with this statement?
What strategies you can take to inculcate value through teaching-learning of physical science? Discuss with examples.

3.8 Is the science teaching-learning, according to you, these days fulfilling the aims discussed above? Explain.

3.9 Make a list of aims of physical science which you believe should guide your teaching-learning process. Discuss them with your classmate and modify the list. You can keep this list with you during practice teaching as a guide.

Chapter 4

Learning Objectives of Physical Science

4.1 INTRODUCTION

We have discussed the various aims of science education in the previous chapter. They provide a broad guideline to align with educational processes. **These aims are the changes in the learning of students that you expect as a result of your endeavour of teaching-learning. Learning objectives guide you to take the required actions to bring those changes and help you to make learning meaningful.** How will you help students to focus their attention on the expected learning activity? What teaching-learning experiences and strategies would you plan to facilitate their learning? How would you help learners to construct and reconstruct their knowledge? What evidences of learning you can observe, gather and document at the end of the lesson? How can you help yourself as well as the learner in self-assessment? Learning objectives help you to find the answers of such questions and perform your work systematically.

In this chapter we shall learn meaning of learning objectives and how to develop them. We shall discuss Anderson and Krathwohl Taxonomy which is Bloom's revised taxonomy. It is illustrated with a number of examples. This chapter also discusses about the learning objectives in constructivist perspective.

4.2 MEANING OF LEARNING OBJECTIVES

Teachers are entrusted with the responsibility to provide learning experiences and opportunity to each learner, so that the learner can learn to the best of her ability and develop her full potential of learning. Identifying certain perceptible changes in terms of remembering, understanding, applying and analysing, etc. that need to be brought out in the learner before transacting a particular topic/unit in the class helps a teacher to discharge this responsibility. These desirable strands of remembering, understanding, applying and analysing for a particular topic/unit in terms of perceived learning are broadly known as learning objectives. **These desirability should be viewed from the perspective of the existing knowledge and background of the learners, not of the teachers.**

In other words, learning objectives are the statements in specific and observable term that tell what the learner is expected to achieve as a result of engaging her in teaching-learning process. For example, *writing three properties of vector product mathematically.*

In the previous chapter we discussed various aspects of the aims of learning physical science like knowledge and understanding of science, nurturance of the process skills, development of scientific attitude and scientific temper, nurturance of the natural curiosity, creativity and aesthetic sense, imbibing values, developing problem- solving skills, and relating physical science education with natural and social environment, technology and society. Many of the above aims are common to all educational processes. It has also been emphasised that achieving aims of physical science should be a continuous effort of the teachers. You may wonder, what are the explicit objectives of learning physical science that can be achieved and observed in a given time? Do the objectives differ from the aims? Let us first see it in Table 4.1.

Table 4.1 Comparing aims and objectives of learning physical science

Aims	Objectives
• Aims are long term statements of purpose that may be achieved over a long period of time, say one or more years. *Example* - Developing a sense of inquiry in learners is an aim that may be achieved over a number of years.	• Objectives are bound in a short and specified time say one teaching-learning period or during teaching-learning of one chapter. *Example* - conducting an activity to generate a question, *why do the electric charges produced by rubbing two rubber balloons are static,* can be one step towards achieving this aim. It is achievable in short time and gives detailed picture of the step you would take.
• Aim is a foreseen end.	• Objectives are influenced by aims.
• Aims are broader in sense.	• You may need to state a number of objectives to achieve one aim. In this sense objectives are narrower.
• It may or may not be easily observable and measurable. For example, *developing interest/curiosity of the learner in science.*	• Learning objectives are easily observable and measurable. For example *applying Ohm's law to calculate resistance of a conductor.*
• Assessment of all the aims may not be objective in nature.	• You can carry on the process of assessment objectively to know whether the objectives have been achieved.

ACTIVITY 4.1

Discuss on the differences between aims and objectives taking few more examples. Do you think there are some more differences between them? If yes, elaborate them.

4.3 DEVELOPING LEARNING OBJECTIVES

Learning objectives of physical science should be consistent with the aims of physical science as well as cognitive abilities of the learners.

Obviously all the scientific facts, principles and theories of science cannot be learnt by all learners and there maybe a qualitative hierarchy in different aspects of learning of a particular learner. For example, a learner maybe very good in experimental skills, but not so in solving numerical problems. You have to keep in mind the nature of science in general and the topic in particular, the scope of the content to be transacted to the learners, the context in which learning is taking place, and needs, abilities and learning difficulties of the learner.

Understanding how to develop learning objectives will help you to structure teaching-learning and assessment processes and optimise learning. Furthermore, classifying the objectives will help you to focus on various aspects of student's learning in their knowledge and cognitive process dimension about which we shall discuss in the next section. Learning objectives should be aligned with three major components of teaching-learning process— the objective, assessment and teaching-learning activities. Whether the objectives are realised or not is known by assessment of learners. Accordingly teaching-learning activities are modified to realise the objectives. Thus, the three components are

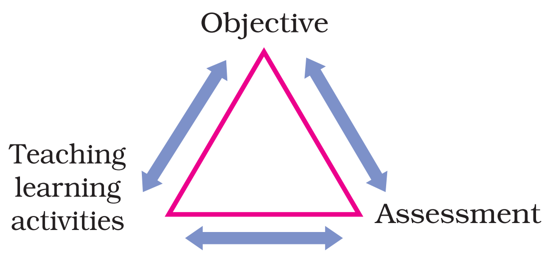


Fig. 4.1 *The three components of teaching-learning process are consistent with each other*

consistent with each other (Fig. 4.1). If three components are congruent, teaching-learning is meaningful.

4.3.1 Features of well-developed learning objectives

A well written learning objective can be easily understood by the learners as well as teachers. Learners can foresee what is expected from them as a result of teaching-learning process and can negotiate with the teacher regarding it. Other teachers can discuss with you and provide suggestions.

You should keep in mind certain focal points for writing learning objectives as depicted in Fig. 4.2.

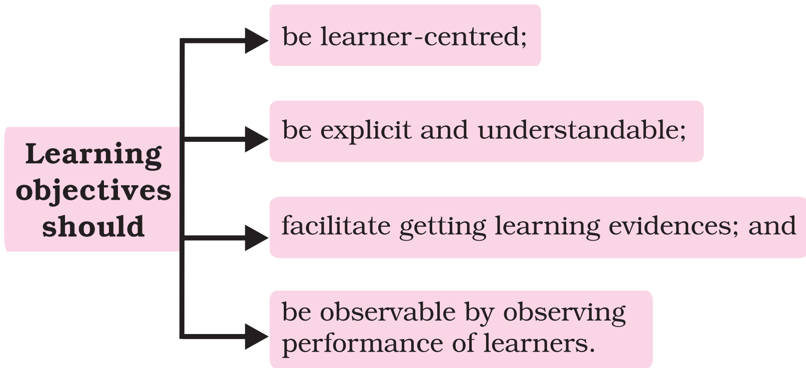


Fig. 4.2 *Writing learning objectives*

Learning objectives should reflect what the learners will do rather than what the teacher will do. Proper use of verbs, which we shall see in the upcoming section, indicating learning process, provides clarity and understanding of a learning objective.

Now examine the learning objectives given as teacher-centred and learner-centred in the two columns in Table 4.2.

Table 4.2 Teacher-centred and learner-centred learning objectives

1. Explaining image formed by a convex lens	• Showing how a convex lens can be used as a magnifying lens. • Using convex lens to observe real image of a distant object. • Performing activity to describe how nature and size of the image change for different positions of the object.
2. Understanding Kirchhoff's law	• Using Kirchhoff's law to calculate current in each branch of a given electric network. • Determining equivalent resistance of a given electric network.

Learning objectives of which column do you find learner-centred? Obviously, those given in the second column are observable, can provide learning evidence and can be recognised.

In order to make learning objectives clear and understandable, the condition under which learning would take place and the criteria for achieving them should also be mentioned. Let us see the following examples.

- *Given the diagram of a human eye*, labelling the structure of human eye.

- *With the help of symbols of chemical elements,* giving the name of elements.
- *With the use of three bobs of different diameters and three strings of different lengths* identifying the factors that affect the time period of a pendulum.
- *After making a model of windmill* describing its working in two paragraphs.
- Showing compressions and rarefactions of a longitudinal wave *with the help of a slinky.*

The more explicit an objective, the more explicit is learning evidences. It is then more likely to be achieved within limited time. Mentioning conditions and criteria in a learning objective gives explicit visualisation for designing learning experiences. **Learners can be actively engaged in deciding learning objectives and the extent of their performance can be negotiated with them. Learning objectives can be changed or modified depending upon the needs of the learners.**

It is important to understand that learning objectives are written not necessarily in the ways mentioned above. Sometimes criteria and conditions both maybe omitted for providing more scope of thinking for learners. For example, writing *Studying various factors affecting time period of a simple pendulum* maybe enough in a certain learning situation for certain learners.

Learning objectives written for a unit should be comprehensive enough to include acquisition of knowledge, understanding, application and skills of science processes as well as problem solving, critical and creative thinking, communication and research in the context of physical science. It should provide opportunities for learning experiences with concrete materials through activities, experiments and projects carrying out investigation and validation of knowledge for the formation of the concepts in physical science. Therefore, **a deep understanding of the contents of the physical science is one of the most important requirements for writing learning objectives.**

ACTIVITY 4.2

Develop three learning objectives on a topic of your choice:
(i) in which condition and criterion of achieving objectives are explicitly written (ii) condition is not written, only criterion is given (iii) criterion is not written, only condition is given (iv) condition and criterion both are omitted.

4.4 ANDERSON AND KRATHWOHL'S TAXONOMY

In 1956, Benjamin S. Bloom classified domains of human learning into three parts — cognitive (knowing; related to head), affective (feeling; related to heart), and psychomotor (doing; related to hand) as the educational objectives. Bloom's taxonomy is a model of classification of thinking into multilevels in increasing order of complexities. As a result of this classification, a series of taxonomies was obtained in each domain that provided a means of expressing qualitatively different levels of thinking of learners.

However, over a period of time new ideas and insight emerged about teaching-learning processes. In order to reflect the changed insight and yield of researches and to meet the needs of the teaching- learning scenario of the twenty-first century learners, Lorin W. Anderson, a former student of Bloom and David R. Krathwohl, one of the co-authors of Bloom's book, led a team of experts in revising Bloom's taxonomy. The result was published in 2001 in the form of a book — *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* (New York: Allyn and Bacon). The revised taxonomy appears similar, yet significant changes are there. Let us now discuss it.

Bloom's taxonomy has six tiers of learning arranged in a hierarchical way. For example, if a learner applies her knowledge, she has already crossed the previous two stages of learning (see Fig. 4.3). With a little change in the hierarchy, revised taxonomy has also six tiers of learning that are more explicit. One of the other significant changes is that revised Bloom's taxonomy has two dimensions identified as the **knowledge dimension** (kind of knowledge to be learnt) and the **cognitive process dimension** whereas Bloom's taxonomy has only one dimension.

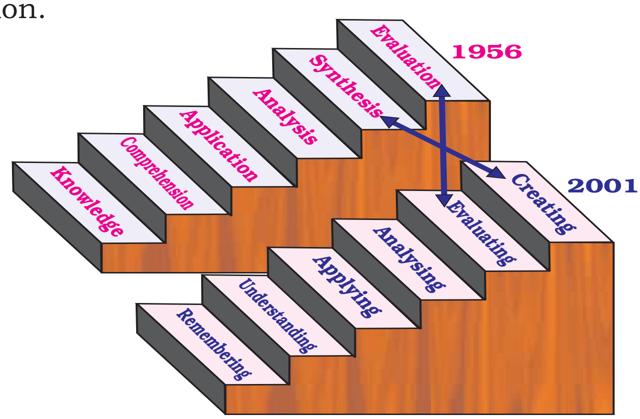


***Fig. 4.3** Revision of Bloom's taxonomy by Anderson and Krathwohl*

The revised taxonomy is different in three ways –

(i) Terminology: It is obvious from Fig. 4.3. This change is minor yet significant.

- It is a shift from the noun to verb words.
- The word *knowledge* was considered inappropriate as a category of thinking and is replaced by *remembering*. **Thinking is an active process and knowledge is the product of thinking.** Knowledge is not viewed as a form of thinking.
- *Comprehension* is revised as *understanding*.
- *Evaluating* has replaced *synthesis* and *creating* has replaced *evaluation*. The word *synthesis* was not very communicative about the learning actions. Therefore, it is replaced by *creating*, i.e. putting the learnt things together in a novel way.
- The subcategories of the six categories are also in the form of verbs.

(ii) Structure: In Bloom's taxonomy, one has to find some ways to cut across different subject areas as the nature and contents of each subject area are different. For example, the factual knowledge of science and language is different. Similarly the procedural knowledge is also different. In languages, this can be speaking fluently; in physical science, this can be performing experiments and activities, using and handling apparatus. Based on the theory of cognitive psychology, Anderson and Krathwohl came up with four dimensions of knowledge. The intersection of the knowledge dimension and cognitive process dimensions gives 24 cells making the taxonomy Table two dimensional as depicted in **Table 4.3.** Crossing of rows and columns shows knowledge and cognitive process being equally important. Let us see the meaning of different dimensions of knowledge in the context of physical science.

Table 4.3 Two-dimensional taxonomy Table given by Anderson and Krathwohl

Knowledge Dimension	Cognitive process dimension					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
Factual knowledge						
Conceptual knowledge						
Procedural knowledge						
Metacognitive knowledge						

Factual knowledge: It is knowledge of facts, laws, definition, ter minology, vocabulary, etc. of physical science. It is specific to physical science and is essential for developing understanding in physical science.
Conceptual knowledge: It is knowledge of theory, generalisation and interrelation of different concepts in physical science.
Procedural knowledge: It is knowledge about scientific processes and inquiry. We come to know how to perform activities and experiments, how to use apparatus and materials for teaching- learning process,
Metacognitive knowledge: It is knowing about knowledge. It is about learner's awareness about her own learning process and learning style. What is her understanding about the way she best learns— listening, working together, reading, writing, doing activities and experiments. Knowing how to describe formation of the rainbow, so that it is approved by the teacher can be one of the aspects of metacognitive learning.

Using the **Table 4.3,** we can match objectives with knowledge dimension and cognitive process dimension. Let us now see how **procedural knowledge** can be matched with **cognitive process dimension** with the help of following example (**Table 4.4**).

Table 4.4 Matching procedural knowledge with cognitive process

Knowledge dimension	Learning objective	Cognitive process dimension
Procedural knowledge	• Making a simple torch recalling the required electric circuit diagram.	Remembering
	• Explaining how does the bulb glow indicating the direction of flow of the electric current.	Understanding
	• Relating glowing of the torch with a closed electric circuit.	Applying
	• Identifying problem in the electric circuit/ components, if the bulb does not glow.	Analysing
	• Selecting suitable electric cell and bulb from a given assemblage for making torch by checking their specifications.	Evaluating

	• Modifying the structure of electric circuit of a simple torch/making a device using simple electric circuit.	Creating

Thus, the structure is different in the following ways.

- One-dimensional taxonomy is revised in two-dimensional form as discussed earlier.
- The order of *synthesis* and *evaluation* is interchanged as the taxonomy is considered to reflect thinking levels in increasing order of complexities. Creative thinking *(synthesis)* is more complex form of thinking than critical thinking *(evaluation).* One can have critical thinking (judging and justifying ideas or things) without being creative (accepting or rejecting ideas to create new ideas or things).
- In Bloom's taxonomy, *evaluation* was the uppermost level of thinking. In the revised taxonomy *creating* is at the top of the hierarchy.

ACTIVITY 4.3

Develop learning objectives on the topic *Carbon and its compound/ Magnetic effects of electric current* at secondary stages matching knowledge dimensions of *factual knowledge, conceptual knowledge, procedural knowledge* and *metacognitive knowledge* with the cognitive process dimensions. Observe how your friend has developed these objectives. Do you think that the objective on the same topic and for the same knowledge dimension can be developed differently? Comment.

(iii) Emphasis:

1. The revised taxonomy is more authentic tool for curriculum planning, developing materials for teaching-learning and assessment processes.
2. Bloom's taxonomy was viewed as the tools best applied for earlier years of schooling. Anderson and Krathwohl taxonomy can easily be used for higher levels also. In this sense, it is broader in use.
3. Emphasis is more on the description of the subcategories of learning. For example,

   Recognising: Locating knowledge in memory that is consistent with presented material.

   Recalling: Retrieving relevant knowledge from long term memory.

The following Table **(Table 4.5)** gives a comprehensive overview of the revised Bloom's taxonomy. The subcategories of the cognitive process provide the form of learning actions and the possible learning products as a result of teaching-learning process.

Table 4.5 A comprehensive view of Anderson and Krathwohl's taxonomy

Category of coginitive process	Subcategory of cognitive process	Learning action	Learning product providing learning evidence
Remembering Retrieving the relevant knowledge from memory.	**Recognising, recalling, finding.**	Recognising, retrieving, finding, listing, naming, selecting, stating, defining, describing, identifying, labeling, recalling, locating.	Definition, fact worksheet, list, label, recall.
Understanding Constructing meaning from the teaching learning materials and processes; getting involved in oral, written, and graphic communication.	**Interpreting, exemplifying, classifying, summarising, inferring, comparing, explaining.**	Explaining, interpreting, summarising, exemplifying, comparing, predicting giving examples, estimating, classifying, paraphrasing, inferring.	Description, explanation, report, diagram, graph, quiz, collection, demonstration.
Applying Using strategies, concepts, principles, theories and procedures in new situations.	**Executing, implementing.**	Implementing, executing, solving, relating, demonstrating, preparing, modifying, showing, using, applying, manipulating, computing, participating.	Demonstration, illustration, presentation, interview, experimentation, records, journal, solution of numerical problems.

Contd..

Categories	Subcategories of cognitive process	Learning actions	Learning products providing learning evidence
Analysing Breaking down knowledge into its components and determining the relationships of the components with one another.	**Differentiating, organising, attributing.**	Analysing, comparing, breaking down, differentiating, structuring, integrating, separating, organising, distinguishing, illustrating, attributing, outlining, making diagram, inferring.	Diagram, graph, model, chart, survey, database, report, checklist, improvised apparatus, questionnaire, spreadsheet.
Evaluating Judging the value of ideas, materials and methods by developing and applying standards and criteria.	**Checking, critiquing.**	Judging, checking, criticising, evaluating, hypothesising, experimenting, testing, monitoring, appraising, justifying, defending, supporting, describing, explaining, relating, interpreting, deciding.	Evaluation, discussion, argumentation, evidence based conclusion, report, investigation, debate.
Creating Putting together ideas or elements to develop an original idea or combining elements; forming coherent or functional whole of ideas and products; engaging in creative thinking.	**Generating, planning, producing.**	Designing, constructing, reconstructing, inventing, making devices planning, producing, generating, reorganising, composing, modifying.	Model, exhibit, project, poster, chart, science drama and play, presentation, game, quiz, song, poem, media product.

Thus, we see that the revised Bloom's taxonomy has a number of subcategories of the cognitive processes. It is more explicit and provides us a powerful tool to help structure the teaching-learning strategies and processes.

ACTIVITY 4.4

'Identifying and developing learning objectives in different categories and subcategories help a teacher to assess her own performance whether she is focussing adequately on the construction of knowledge of learners.' Conduct a group discussion on this issue in the class.

ACTIVITY 4.5

Observe one period of a physical science class of a practising teacher and note down: (i) How many knowledge dimensions of the concept were transacted? (ii) What cognitive process learners were involved in during transaction of those dimensions of knowledge?

ACTIVITY 4.6

Given below are some learning objectives on the topic *Thermodynamics* at the Higher secondary stage. Identify category and subcategory of the learning process in the cognitive process dimension. To which knowledge dimensions would you place these objectives? Mention them in Table 4.6.

Table 4.6 Learning objectives on Thermodynamics matching cognitive process dimension and knowledge dimension

Learning objectives	Category of cognitive process	Subcategory of cognitive process	Knowledge dimension
• Explaining heat is a form of energy and conversion of energy from one form to another by performing activities.	analysing	organising	procedural knowledge
• Describing the meaning of thermal equilibrium.	....	....	....
• Differentiating between an adiabatic wall and a diathermic wall.	....	....	....
• Explaining the zeroth law of thermodynamics with the help of a diagram of two systems.	....	....	....
• Defining a thermodynamic system with the help of examples.	....	....	....
• Analysing the relationship between internal energy, heat and work by observing simulated experiment on the computer.	....	....	....
• Giving two examples in which			

Contd...

Learning objectives	Category of cognitive process	Subcategory of cognitive process	Knowledge dimension
the internal energy of a system can be changed.	....	....	....
• Stating the first law of thermodynamics, giving two examples in which the law is demonstrated.	....	....	....
• Representing the First Law mathematically.	....	....	....
• Deriving mathematical relation between specific heat capacity at constant volume and specific heat capacity at constant pressure.	....	....	....
• Organising the ideas on thermodynamic state variables and equation of state by performing an activity using a cylinder and a piston.	....	....	....
• Defining and giving illustrated examples of each of the following thermodynamic processes: (a) adiabatic, (b) isochoric, (c) isothermal, and (d) isobaric.	....	....	....
• Interpreting on the basis of examples that there is a fundamental limit on the efficiency of a heat engine set by an independent principle of nature, called second law of thermodynamics.	....	....	....
• Observing a model of a steam engine/internal combustion engine to explain that heat engine is a device that undergoes a cyclic process of conversion of heat to work.	....	....	....
• Determining the efficiency of a heat engine in terms of input temperature and output temperature.	....	....	....
• Describing reversible and irreversible processes with illustrations.	....	....	....
• Differentiating between Carnot			

Contd...

Learning objectives	Category of cognitive process	Subcategory of cognitive process	Knowledge dimension
Efficiency and actual efficiency as applied to heat engines.	....	....	....
• Devising an experiment to measure the work done in an isothermal process.	....	....	....
• Interpreting and making calculations from *PV* diagrams. • Solving problems based on the various concepts of thermodynamics.	....	....	....

4.5 WRITING LEARNING OBJECTIVES

4.5.1 Remembering

Learner recalls and recognises the facts, definitions, laws, principles and other bits of knowledge from her memory. It helps the learner in understanding science.

For helping learners to recall and recognise the names of compounds learnt in chemistry, the teacher can provide in the class the simple root, prefixes, suffixes that can provide clues to numerous other words which will help them to learn new vocabulary. It can enhance their interest in science. For example, teacher can give a rootword *carb*. Using this rootword, learner can write the other words in chemistry like *carbohydrate, carbonic acid, carbon dioxide, carbide, carboxylic acid*. As an example of prefix, the teacher can give prefix *electr* and learner can give examples like *electrolyte, electricity, electrode, electromotive force, electric field.*

Such activities can help learners to develop scientific vocabulary. Performing various activities and experiments in science and interacting with students using repeated use of these words also help them to learn scientific vocabulary.

Learning Objectives: examples

- Identifying convex and concave lenses by touching them and observing images formed by them.
- Recalling the definition of real and virtual images.
- Stating one situation where a virtual image is formed.
- Listing two uses each of a convex and concave lens.

For teaching learning of the concepts on *Solution* at upper primary stage, the teacher may plan the learning objectives in the cognitive process dimension of remembering in the following manner.

- Identifying types of solution.
- Listing different types of solutions.
- Selecting solutions from the list given below – milk, water, salt solution, ethanol.

4.5.2 Understanding

Learner constructs meaning in various teaching-learning situations. She understands if she can correlate and connect different concepts and bits of knowledge. Understanding supports logical and abstract thinking.

Learning Objectives: examples

- Describing distillation process.
- Summarising various steps involved in distillation.
- Distinguishing between simple distillation and fractional distillation.
- Illustrating fractional distillation by taking an example.

Performing an activity to find out conditions under which iron rusts by placing three iron nails separately in three corked test tubes containing tap water, boiled water and anhydrous calcium chloride respectively.

- Giving scientific reason for rusting of iron after performing the activity.
- Explaining the conditions under which iron nails rust.
- Inferring that if iron articles are exposed to moist air for a long time, it acquires rusting.

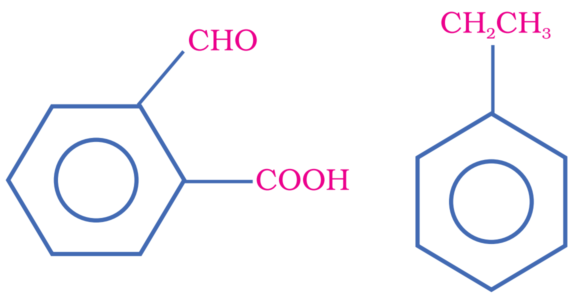
4.5.3 Applying

Learner can use facts, concepts, principles, theories and solve problems in new situations.

- Sometimes people show blood coming out of vegetables and spread belief that this is because of some divine power. If learner knows that *ferric ion* forms a complex with *thiocyanate* ion and gives red colour, then they may provide scientific explanation for the cause of these phenomena.
- During a thunderstorm or a cyclone we open our doors and windows to prevent the house from damage, by using the knowledge of Bernoulli's principle.
- Class X students ask question to their teacher, "Why do stars twinkle and planets do not twinkle?" Teacher helps them to apply laws of refraction to explain reason for twinkling of stars.

Learning Objectives: examples

- Demonstrating at least one chemical test of alkali-metals.
- Predicting the presence of alkali-metal in a given sample.
- Using the concept of H-bonding to explain solubility of benzoic acid in H_2O.
- Balancing the following reaction –
  $Zn(s) + HNO_3 \longrightarrow Zn(NO_3)_2 + NH_4NO_3 + H_2O$
- Giving the IUPAC name of the following compounds:



- Performing an activity using a current carrying coil and a magnetic compass to show magnetic field due to electric current.
- Drawing a figure of field lines of a magnetic field around a straight conducting wire.
- Applying right hand thumb rule to find the direction of magnetic field associated with current carrying conductors.
- Applying right hand rule to find out the direction of the magnetic field inside and outside of the loop.
- Relating the field lines of a magnetic field through and around a current carrying solenoid with the field lines around a bar magnet.

4.5.4 Analysing

Learner can see patterns, recognise inherent meaning and identify components.

At the level of analysing, the learner is in a position to *compare, attribute, organise, breaking down knowledge into its constituents.* The learner can analyse a given situation. She is in a position to differentiate between constituent parts of a given problem and recognise the relationship between them. For nurturing scientific understanding the teacher can present analogies to further enhance their understanding of the concept. This includes identification of parts, analysis of the relationship between parts and recognition of the organisational principles involved.

- The structure and function of the eye can be compared to a camera. Thus, while transacting the concept of lens in physics , the lens of the eye can be compared with the convex lens of a camera. Image formation by the lens of the eye can be compared with the image formation by the convex lens of the camera.
- A mixture of sulphur and iron is provided to you. How can you separate them from each other?

  On the basis of the previous knowledge that sulphur is soluble in carbon- disulphide while iron is not, learners realise that the problem of separation can be solved by using carbon disulphide. They also realise that iron can be separated from sulphur by using a magnet.

Learning Objectives : examples

- Pointing out that oxygen rich compounds are oxidising while others are reducing agents in the following examples. $LiA\ell H_4$, $KMnO_4$, $K_2Cr_2O_7$, $NaBH_4$, K_2CrO_4, CrO_3, H_2 in presence of Pt/Ni.
- Pointing out the number of electrons transferred in the following reaction during oxidation and reduction.
  $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$
- Organising a solenoid, an iron rod, a battery and a key to show making of an electromagnet.
- Solving numerical problems related with various concepts in physics and chemistry.
- Making interpretation of the elastic behaviour of the materials from the given set of stress-strain curves.

4.5.5 Evaluating

Learners can evaluate, generate, critique, judge, formulate hypothesis of scientific concepts, and plan experiments. They can justify a decision or course of action.

Critical thinking is a process of analysing and evaluating information to determine its validity in a given situation. In order to develop critical thinking discussion should be carried out during activities and experiments and learners should be given problems to be examined. They should be encouraged ask questions and identify the assumptions, define criteria and judge the accuracy of data or information. In this way they can collect enough evidences to arrive at a conclusion.

Learners should be given opportunity to solve problems and follow various steps in the process like gathering related data, formulating hypotheses, finding alternate solution and choosing the best solution in the light of the given situation. These strategies of teaching-learning help teacher to achive learning objective of evaluating category.

Learning Objectives: examples

- Commenting on the trend of electro-negativity while moving down the group and moving across the period in the Periodic Table.
- Relating variation in atomic number with trends of electro-negativity along period and group in the Periodic Table.
- Commenting on the statement: *Redox reaction is combination of oxidation and reduction*.
- Concluding that the basic requirement for the separation of a liquid mixture is the process of distillation.
- Justifying the statement: *A liquid mixture with a small difference in the boiling point of the components is separated through fractional distillation*.
- Justifying the streamline shape of the objects moving in fluids.
- Evaluating the criteria for the selection of lenses in microscope and telescope.
- Investigating the factors on which strength of an electromagnet depends.
- Evaluating the environmental consequences of the increasing demand of energy.
- Evaluating the strength of a material from the stress-strain graph.
- Justifying the use of thick metal rope in lifting heavy objects by a crane, based on its stress versus strain relationship.

4.5.6 Creating

Creating implies designing, planning, writing, constructing, and producing through one's own imagination.

There are certain topics in science where learner can be given certain activities to collect data, gather information from various sources and generate scientific understanding of the concept in detail. Learner can work like a researcher and develop qualities like perseverance, respect for others' ideas and arrive at conclusion after collecting enough evidences. They should be given opportunity to arrive at scientific concepts by doing some activity. For example, learner can collect data from a locality to study the sources of water pollution and their effect on the health of people in that locality.

- When a learner constructs her knowledge about a concept, she needs to communicate her understanding to others. The communication may be done either through writing work or through verbal communication in the form of a debate, discussion, etc. This can be made possible by organising activities like presenting a poster or seminar in the class. Learner can even be encouraged to present her understanding by presenting findings in the form of a *Venn diagram* or *a flowchart*. It can be done on many topics such as *Fiber, Properties of Metals and Non-metals*.
- Teacher gives a project to the learner on *climate change : cause, effect and solution*. Learner collects data from varied sources like web sites, reference books, etc. After collecting information, the learner present her understanding of the topic in the class and discusses in detail. In this way the learner can develop an ability to express her ideas in a logical manner.

Learning Objectives: examples

- Constructing an electrochemical cell from the given list of half cells.
- Communicating working of electrochemical cells to peers by developing a model.
- Combining the following two half reactions to form redox reaction.

  $Zn(s) \longrightarrow Zn^{2+} + 2e^-$

  $Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$
- Preparing presentation on importance of redox reactions taking examples from day to day life.
- Making a model of windmill.
- Conducting a survey on the awareness of people about sources of air pollution in their localities.
- Preparing a PowerPoint presentation on the earth's magnetism.
- Enacting a play showing structure of the solar system.
- Making toys using magnets.
- Improvising an experimental set-up to draw stress-strain curve of a rubber (or various materials) string.

Above examples of the learning objectives are only illustrative, not prescriptive or comprehensive.

Learning Objectives in Terms of Learning Strands

Latest researches in science education are guiding us for a reform to write learning objectives in the form of perceptible changes in learner. Learning objectives can be classified under **six strands** of learning. Considering that learning takes place in formal as well as in the informal environment, the strands are statements about what learner will do while learning science with respect to conceptual, practical, abstract and reflective aspects of science learning. All strands of learning are intertwined with each other like strands in a rope and therefore teaching-learning experiences should integrate these strands altogether for meaningful learning. Learning of one strand supports learning in other strands (Bell, 2009).

Objectives which are organised within learning strands are given below.
Strand 1: Interest, excitement, experience, and motivation to learn about natural phenomena.
Strand 2: Generate, understand and use facts, concepts, explanations, arguments and models related to science.
Strand 3: Observe, question, explore, test, manipulate, predict, make sense of natural and physical world.
Strand 4: Reflects on science as a way of knowing: on processes and concepts of science and on their own process of learning about phenomena.
Strand 5: Participate in learning practices of scientific activities with others using scientific language and tools.
Strand 6: Think about themselves as learners of science and develop an identity as someone who knows about science and contributes to science.
These strands of learning supports intertwined nature of learning in different areas and provide a framework for writing learning objectives.

Examples of organising learning experiences under different strands of learning are given below:

- **While learning the concept of Heat and temperature learner:**

Strand 1: Experiences the use of thermometer in measuring temperature in the process of heating water.
Strand 2: Generates a model of understanding 'temperature change,' during the process of heating water.
Strand 3: Makes predictions about the 'applicability of model of temperature change,' to other liquids.
Strand 4: Reflects on the 'model of temperature change,' during the process of heating water.
Strand 5: Uses scientific language in describing the model of temperature change developed. For example, learners describes their model of scientific terminology like *Celsius scale, Fahrenheit scale, latent heat* and *convection.*
Strand 6: Identifies their own contribution in science by developing a model of temperature change. For example, learner evaluates her model vis-a-vis models made by other learners in terms of its efficacy.

- **In another example of learning the concept of *Heat*, the learner:**

Strand 1: Experiences that when at home anyone is sick, his/her temperature is measured with the help of a thermometer.
Strand 2: Understands that whenever a person is sick or is having fever, the body temperature increases.
Strand 3: Measures the temperature of 10 to 15 persons to collect the data and draws conclusion about the normal body temperature of a person.
Strand 4: Reflects on the observations made and draws relevant interpretations.
Strand 5: Makes use of thermometer for measuring body temperature; describing the process using words like *Celsius scale, Fahrenheit scale* and *conversion of temperature.*
Strand 6: Contemplates about her understanding of the concept and makes people/community/peer aware about body temperature of a healthy person.

ACTIVITY 4.7

Search various websites to know more about learning strands. Discuss the rationale behind using them.

ACTIVITY 4.8

Read out carefully any topic say, '*Force and Pressure* at secondary stage'. Develop learning objectives of each category/each strand and share your ideas about suitability of particular learning actions for achieving these learning objectives.

4.6 ILLUSTRATIONS ON LEARNING OBJECTIVES FOR UPPER PRIMARY, SECONDARY AND HIGHER SECONDARY STAGES

Learning objectives of the same theme or topic are different at upper primary, secondary and higher secondary stage. At upper primary stage, the learners are encouraged to learn principles of physical science through observation and concrete examples relating to their everyday life experiences. They are engaged in simple activities, models and projects. Group activities, discussion with peers and teachers, surveys, organisation of data and their display through exhibition, etc. in schools should be an important component of pedagogy. At the secondary stage, abstraction and quantitative reasoning come to occupy a more central place than at the upper primary level. Therefore the learners can be introduced to the abstract concepts of physical science by involving them in systematic experimentation. At higher secondary stage, emphasis is given on the rigour and depth of science and problem-solving by involving them in advanced technological experiences.

Therefore, while writing learning objectives the depth, breadth and complexities of concepts, and the suitability of learning experiences have to be considered according to cognitive level of the learners at different stages of learning. For example, the topic on *Light* can be dealt in different ways at upper primary, secondary and higher secondary stage. At upper primary stage the concept of reflection of light and shadow formation are dealt with the help of concrete examples trying to relate the concepts of light with day to day observations. At secondary stage, the disciplinary approach just begins to emerge and more rigorous emphasis is given on the explanation of natural phenomena. But still the topic is discussed as a part of composite science. At higher secondary stage, it takes the shape as a discipline of physics. In-depth study of the topic with more rigorous mathematical expression and advanced experiments is required at the higher secondary stage.

Let us see, how we can write learning objectives on the same topic *Light* at upper primary, secondary and higher secondary stage.

THEME – LIGHT

Upper primary stage

- Identifying transparent, opaque and translucent objects from the given materials by observing through them.
- Distinguishing transparent materials from translucent materials.
- Discriminating between shadow and image.
- Inferring that light travels along a straight line by observing a candle through a straight and then through a bent pipe.
- Making a model of a pinhole camera.
- Concluding that white light is composed of seven colours by observing a beam of sunlight through prism.
- Performing an activity to understand laws of reflection using a plane mirror and pins.
- Stating the laws of reflection of light.
- Drawing a labelled diagram of human eye, etc.

Secondary stage

- Comparing the nature of images formed by concave and convex mirror.

- Representing images formed by concave and convex mirror using ray diagram.
- Writing lens formula.
- Performing an activity to observe nature, position and relative size of the images formed by spherical lenses for various positions of the object.
- Solving numerical problems based on the lens formula.
- Describing three defects of vision (myopia, hypermetropia and presbyopia) and the way of their correction.
- Explaining dispersion of white light through a prism.
- Applying the understanding of the phenomenon of refraction to explain the blue colour of the sky and red colour of the sun at sunrise and sunset, etc.

Higher secondary stage

- Applying laws of reflection to explain total internal reflection of light.
- Explaining formation of mirage on the basis of total internal reflection.
- Describing technological application of total internal reflection in the form of optical fibres.
- Deriving expression for the refraction at spherical surfaces.
- Deriving expression for the focal length of combination of lenses in contact.
- Deriving expression for the refractive index of the material of the prism mathematically.
- Performing experiment to draw i-δ curve.
- Describing construction and working of a microscope/ telescope.
- Identifying errors in the given ray diagrams.
- Evaluating suitability of spherical lenses for the construction of a microscope/telescope from the given values of the focal length of the lenses.

From the above examples, you can make out that **learning is an ongoing and continuous process and not a product. Therefore learning objectives should be evolving in nature based on your analysis of the concept(s) to be transacted and in consonance with the cognitive level, context and needs of the learners.**

Above **examples of learning objectives are illustrative and not prescriptive**. The hierarchy of the cognitive processes may require some change depending upon the need, interest, abilities and attitudes of the learner. One of the important things to be considered in writing learning objective is that a teacher should not concentrate on only one category of learning.

ACTIVITY 4.9

As a group work, develop learning objectives of various cognitive processes on the following topics for different stages of learning.
(a) Mechanics (b) Magnetism (c) Electrostatics (d) Electricity (e) Acids, bases and salts (f) Nature and states of matter (g) Metallurgy.
Each group may give presentation in the class and discuss to modify them.

4.7 LEARNING OBJECTIVES IN THE CONSTRUCTIVIST PERSPECTIVE

Traditional approaches as discussed above has led us to identify and write learning objectives in advance, so that proper planning (lesson planning) may take place well according to pre-identified learning objectives irrespective of the learning situations and learner's needs. This stand is not acceptable to constructivist approach. In the constructivist perspective, knowledge, understanding, application, skill, etc. or remembering, understanding, applying and analysing, etc. cannot be visualised, different from one another as no knowledge is possible until and unless there is understanding on the part of the learner. Even skill is sometimes viewed as one of the outcomes of knowledge and understanding. In other words, **a concept cannot be divided into different levels of learning. It has to be an integral whole.**

Beginning of a lesson planning is probably most difficult time to create specific detailed learning objectives well in advance irrespective of the learning situations and learners' circumstances. That is when there is the least agreement among students and the teacher about what should be learned. The beginning is also difficult time to know what understanding will emerge during transaction of the lesson.

During the teaching-learning process, if the original learning objectives and teaching-learning design do not match, teacher changes the objectives according to the needs of the learners rather than changing the design. She can add on some objectives, if she finds that some more objectives are required to address the learning needs of learners, she can cut back on more ambitious learning objectives. Here questions arise — by the time teaching-learning process based on a certain concept of physical science is concluded, the learning design meets the objectives — or the objectives effectively preview the learning design you had created? Is it spiral? Do we need to have objectives when we start teaching-learning? Or, the learning objectives emerge across the design and development process? It is a matter of deep concern for teaching-learning of science.

Learning is a *divergent process* that occurs through various exposures and not necessarily through a common, singular exposure predicted by teacher. It is essentially a participative process in which learner constructs her knowledge in her own ways, through absorption, interaction, observation and reflection. In the process, learner goes back and forth. The process therefore *is not linear;* it is rather spiral and complex in nature.

Learning is thus a multidimensional process and it should centre around certain key concepts. Teacher needs to continually assess learners' understanding of the concepts. Learners' viewpoints should be sought and valued. They should be encouraged to ask questions. Based on their viewpoints, ideas and questions on the concept, learning objectives should be constructed and reconstructed on a continual basis during teaching-learning of physical science. It can help in observing existing knowledge of the learners and addressing their misconceptions and naive concepts. Teachers may change the learning objectives to fit the cognitive development of the learners, instead of rigidly sticking to a pre-planned agenda.

In the constructivist perspective, learning objectives are contextual in nature. Learners construct their own meaning. We cannot guarantee they will learn specifically what we intend, but we can craft an environment that is likely to help them to develop ideas and practices that are in alignment with what we intend. It is unreasonable to think that we can nail everything we need to know about a lesson before we even begin to design our learning strategies. The world is too complicated for that, and the variables that influence our teaching-learning are too numerous. However, that does not mean teacher needs to work without learning objectives. **Teaching- learning can be organised around certain broad and integrated key concept**. For example, the concepts on the topic *Reflection of light* for Class VIII can be, *light makes things visible; experimental verification of the laws of reflection; regular and diffused reflection; reflected light can be reflected again; multiple images formed by plane mirror and kaleidoscope.*

The learning objective can be planned with the help of learners by discussion, and involving them in inquiry and providing them opportunities to perform activities, ask questions, enter into argumentation, etc. For this, **developing a strong understanding of the concepts of physical science; the learning process; and the learner have to be among first priorities for teachers.**

Learner's experience has an important place in the process of knowledge construction and understanding of the concept. **Experience is perhaps the most important step in the process of discovery of science through which each learner can be made to feel, reflect, and arrive at ideas**. Therefore, teacher's understanding of learner's experiential base is very important in the formation of learning objectives and choice of pedagogy. Relating to what they have already experienced helps in the process of reflection. It is a continuous challenge for teacher to look for suitable ways of 'creating' and 'drawing upon' experiences.

New experiences for teaching-learning of physical science can be organised in several ways. It could be through a process of observing something happening; performing activities, experiments and projects; or by going through the mental process of reflecting on something the learner has experienced. Lived experiences in the form of exercises that help learners to relate to life outside the schools or in terms of created experiences in the school have values at all stages of education. Only the nature, kind and complexity of the experiences that the teacher wants to plan for students, need change over the years.

Sundaram had to transact the concept of magnetism to the learners of Class VI. He carried two magnets and one compass needle, few safety pins, nails (and some other magnetic materials) to the class and allowed his students to play with these materials for around 10 minutes. He announced, "You can bring these materials near each other and then keep them at various distances and see what happens." Students became very happy to play with these materials as they liked. They started asking questions— "What is this (compass needle)?" "Why do the safety pins and nails stick to magnet?" "Why does the needle of compass move when a magnet is brought near it?" "What is the use of compass needle?" "I want to know more about magnet. Can I play more with this compass needle?" etc. Acknowledging and starting with the students' questions, Sundaram set up the learning objectives. He transacted the concepts of attractive and directive properties of magnets. He facilitated students to find the North-South (N-S) direction in the classroom using the compass needle.

Learners might need assistance setting learning objectives. Learners interact dynamically with others and the world around them and continually construct and reconstruct their knowledge. Providing learners environment of learning encourages them to get involved in developing learning objectives, personalises their learning and gives an ownership to their learning.

During teaching-learning process teacher may frequently ask students to **'think-pair-share.'** A learner may discuss on the topic with the learner next to her and write two-three questions for which they do not have answers. **Teaching-learning experiences can be designed starting from their questions. Teacher needs to have deep understanding of the concepts on the topic being transacted to anticipate learners' questions and keep the interaction focused towards construction of knowledge of the learners on the concerned topic.** It can provide learners opportunity to relate the ongoing learning with their previous experiences. In order to better understand, it is important that learners identify questions to be resolved and take lead towards identifying learning objectives.

Science does not exist as a body of knowledge separate from the learners. **Teacher has to recognise that in learner-centred learning situations, curriculum 'evolves' and is not 'predesigned' for providing possible support in the process of construction of knowledge**. Every subsequent learning situation cumulatively provides better insight to the teacher in discovering learners' needs and identifying varied support for learning. In this sense teacher is a participant in learners' effort at evolving learning experiences.

ACTIVITY 4.10

Jot down a list of key concepts for transacting the concepts on the topic *Chemical Reaction*. Discuss how would you draw upon learner's ideas and experiences to develop learning objectives on this topic. Think-pair-share your ideas in the class.

4.8 SUMMARY

Learning objectives are very important from the perspective of students and teachers both. They give direction to the teacher to plan learning experiences to be organised for a class and decide the ways and means to assess them.

Learning cannot be seen directly. Therefore we have to find some indicators of learning from the evidences we can see. Learning objectives if constructed properly provide simple ways for developing those indicators. Since learning objectives are written in terms of task that learners will perform, teacher can easily assess learners' performance in the class and get their feedback. We shall discuss about Learning Indicators (LI) in detail in Chapter 11 *Tools and Techniques of Assessment for Learning Physical Science.* Learning indicators help in monitoring formation of concepts of the learners and their progress in different areas of learning.

As we all observe that children are curious by nature. Given the freedom they often explore and interact with things around them for extended periods. These are valuable learning experiences, which are essential for imbibing scientific inquiry, but may not always confirm to adult expectations. It is therefore vital to keep their disposition in view in developing learning objectives and give them the needed space for learning. **The developed objective should be flexible according to the needs of the learners and teaching-learning situations**. It should serve as a guide for teaching-learning process rather than a constraint. **Our ultimate aim is to help children learn to become autonomous learners.**

Formulating learning objectives help the teacher to remain more flexible as she has more options to choose to accommodate the learning needs and interests of the students. Teacher should encourage students to ask questions. If she observes some learning gap, she should revisit learning objectives adding new one so as to cover any important aspect of the concept that was not there earlier. **Questions and experiences of learners should be valued more than the pre-decided objectives**

and be used to select learning objectives. Learning in science is characterised neither by learning content, nor by learning process alone, but by the judicious mix of content, process and the context of the learner, the society and whole school experiences.

A deep understanding of learning objective in traditional as well as constructivist perspective helps in designing teaching- learning experiences in the class and meet the needs of a learners.

EXERCISE

4.1 What do you mean by learning objectives? What do you think should be the features of a well-developed learning objective? Illustrate with examples.

4.2 'Aims and learning objectives of physical science operate in close conjunction with each other.' Comment.

4.3 'Learning objectives of physical science have their roots in the aims of physical science.' Illustrate it taking the help of any concept.

4.4 What is the importance of developing learning objectives? Explain with the help of a few examples.

4.5 Select a topic of your choice in physical science. Develop at least two learning objectives corresponding to each of the subcategories of learning as given by Anderson and Krathwohl taxonomy.

4.6 Write down the learning objectives for any three activities and three experiments in physical science at different stages on the theme *Light/ Acids, Bases and Salt.*

4.7 Prepare a questionnaire to know how do writing learning objectives help a teacher in teaching-learning process. Conduct an interview with a few practising teachers of physical science. Analyse the collected data and present a report in the class.

4.8 Observe a science/physics/chemistry class of a practising teacher. Observe what learning objectives are being achieved in the class? What teaching-learning experiences have been designed for this? Report your findings to your teacher-educator.

4.9 Discuss how will you develop learning objectives in constructivism perspective ? Support your ideas with examples.

Chapter 5

Exploring Learners

5.1 INTRODUCTION

We have already discussed about aims and learning objectives of physical science in the last two chapters. We have come to an understanding that well-developed learning objectives should be flexible according to teaching-learning situation and the need of the learner. You will appreciate that each learner is different from the other in terms of intellectual, emotional and social needs. Their motivational levels of learning physical science are also different. They are not same with respect to their knowledge, experiences, interests and the abilities. These differences can be seen even in one individual over a period of time. All these variations contribute in the way they learn and the knowledge they acquire.

Furthermore, we observe that learners construct their knowledge of science by interacting with the learning materials available in their environment in their own way. Knowing and creating the learning environment through various activities and investigations helps you in the process of teaching and learning. It helps the learners to relate their learning with their everyday life experiences. **In order to maximise their learning and facilitate them to utilise their wide range of potentials in a variety of teaching-learning situations, it is necessary to explore your learners.**

Dictionary meaning of exploration is to investigate systematically. In the context of teaching-learning situations and processes, exploring the learners implies knowing your learners and their learning situations. The questions arise— Why should you know your learners? What should you know about them? How can you know about them? Let us first look at the answers of these questions through a broad framework. Firstly, you should know your learners because each learner is unique. Secondly, you should know about their previous and naive ideas of scientific concepts, their learning needs and the variety of ways they learn physical science. You have to find how they are constructing their knowledge and the extent of their learning. All these help you to plan your teaching- learning experiences and processes. Thirdly, you can know about the learners by creating conducive learning situations. Learners should be involved actively in the teaching-learning process by motivating them to bring their previous and naive ideas of the concepts in physical science, appreciating dialogue among peer group, getting them engaged in discussion and arguments, and facilitating them to mediate and negotiate learning. You should encourage them to collect learning materials from local resources for various activities, experiments and projects. For all these purposes, you need to provide them opportunity to raise and ask questions and express wonders on science and you have to cultivate the habit of listening to the learners. In this chapter we shall discuss about them in detail.

5.2 EACH LEARNER IS UNIQUE

We have discussed above that every learner is different from the other. You may ask yourself, “Why should I know individual differences among the learners when I have to teach the ‘same content’ to all of them in my class?" You can get the answer by recalling your own experiences. Recall some of the teaching-learning situations of your school days, where the teacher had taught the 'entire class' the 'same content' in the 'same way'. What was the result? Did all the learners learn the 'same thing' at the 'same level'? Did they get the 'same marks or grades' when examined by the teacher? If not, then, why? Did you ever feel like sharing your experiences with the teacher and classmates during teaching-learning process?

Do all learners learn the same thing at the same level?

You will find learners in your class with a wide range of educational experiences that you should consider in planning teaching-learning experiences. Some have read a number of books, some have worked on many projects at the previous stages of learning, while some have travelled to various places. Different learners interact with different people and they observe and interpret their environment differently. All these factors contribute to the difference in their experiences. They construct their knowledge differently by relating it to their previous experiences. Therefore taking into account the heterogeneity of the class as well as uniqueness of the learner and paying attention to the existing ideas of the learners brings enrichment in teaching-learning experiences. At the same time, this makes the learners feel valued and motivates them to get actively involved in the learning process.

ACTIVITY 5.1

Talk to your friends about their educational experiences, interests and the way they prefer to learn, etc. Do you find that each of you are different from each other in learning experiences and learning needs? Reflect over this issue.

5.3 MOTIVATING LEARNERS TO BRING THEIR PREVIOUS KNOWLEDGE INTO CLASSROOM

Learners' experiences and observations of real-life situations and their previous knowledge should be used in teaching-learning of science. They should be motivated to participate actively in the teaching-learning process for construction of their knowledge. Emphasis should be given on their involvement by facilitating them to experiment, form hypothesis, modify, discuss, infer, justify, defend, argue, analyse, solve, put question, relate, organise, use, apply, critically examine, explain, and interpretate. Teacher should nurture a learning environment where learners can get motivated to share their previous experiences and knowledge without fear and take initiative to participate. You would find classroom with such an environment a very lively place in the pursuit of quality learning that helps learners to develop a sense of inquiry and scientific attitude.

Providing situations of observations can arouse curiosity among learners and generate questions in their minds. For example, you can start the lesson on *Combustion* or *Flame* by burning a candle and a spirit lamp (taking necessary precautions) and ask the learners to observe the two flames and give their observations.

Student's attention can be drawn towards:

- size of the flame;
- brightness of the flame; and
- colour of the flame, etc.

To relate the concept of combustion with the experiences of the learners in the classroom you can also help them to compare other flames they might have seen, such as the following:

- Flame of the burner in the kitchen.
- Flame of the burner used by the blacksmith.
- Flame of burning wood/paper/cow dung cakes, etc.
- Flame of things burnt at bonfire.

Here you are bringing the experiences and the previous knowledge of the learners about the flame in the classroom. **When the learners are able to relate the classroom learning experiences to their observations and experiences outside the world, it works as a motivating factor for them to participate in the learning process.**

While discussing on *Chemical reactions,* Sameer, a secondary school teacher makes an effort to motivate the learners to share their experiences about the changes they observe around them and to think about the process of making things they use daily, e.g.– soap, toothpaste having different colour, smell and texture, synthetic clothing materials, etc. Some of the questions he discusses with them about transformation of chemical substances are as follows:

- What changes do you observe when things like paper, wood, candle, cloth and metal such as magnesium burn?
- What happens when an object made of iron is heated?
- What happens to metals left in the open moist area?
- Why does the food get spoiled if left in the open?
- Why is the colour of cooked food different from the raw food stuff?
- What happens when an acid reacts with a base?
- How will you know if a substance is acidic or basic in nature?

He finds that students themselves come up with many more such questions and start finding the answers through dialogue and discussion. Sameer facilitates them to perform some activities and carry out investigations to satisfy their own queries. He observes that students get interested and motivated to learn the answers to their own queries.

Before starting the lesson you should ensure that the learners are ready to learn. You need to know that learning takes place in a variety of ways— through reading, asking, listening, writing, making and doing things, experimenting, discussing, thinking and reflecting, and expressing oneself through speech. They may perform these activities individually or with others. You can motivate the learners to share their existing knowledge and ideas by providing such opportunities to them.

Holidays had started. Pragya and Pratyush were at home. Their parents had cooked their favourite curry and rice and gone for work. Pratyush dropped some curry on his white T-shirt while eating. They decided to wash and clean the stain. But as Pratyush rubbed soap over the curry stain, something amazing happened, the stain became orange-red in colour. Baffled over the change in colour, pragya and pratyush put the T-shirt for drying. As soon as their mother was back they asked her a lot of questions as they narrated their experience. Their mother said, "you observed this because soap is basic in nature and it turns turmeric yellow to orange-red." They became curious to know the reason of change in colour and got motivated to learn more about acids and bases.

Encourage learners to share their experiences, clear their doubts and share their existing ideas with the class. There is a lot of science in their experiences. Those experiences and ideas can be used as a stepping stone to learning scientific concepts. When learners are encouraged to share and seek out knowledge from sources other than the textbook, in their own experiences, in the experiences of their peers, homes and surroundings, outside the school, in the laboratory and library, they realise that knowledge can be sought out, authenticated and constructed.

We have discussed above that learners in a classroom have different experiential background. Based on their experiences of natural world they form some ideas/notions/beliefs of a concept or process. These ideas are alternative framework (alternative conceptions) that may be right or wrong. If wrong, they should be removed from cognitive framework of the learners. These are *misconceptions*. If learners' previous ideas do not match with the scientific explanations and are partially correct, these are *naive concepts*. Recognising the evolving nature of cognitive development of the learners, they should be facilitated to construct new ideas over their naive ideas. **When we talk of naive ideas we recognise that knowledge is always being constructed. We need to view the learners as constructing knowledge all the time.** This is true not only regarding science or any discipline, but equally regarding values, skills and attitudes.

Learners' mental representation of ideas are continually adopted, reformed and revisited in the process of construction of their knowledge. Teaching-learning of science helps them to develop their ideas in particular ways. Active involvement of learners in intellectual stimulation with new and other's ideas, in social interactions with teachers and peers and their physical interaction with phenomena and materials, can bring conceptual changes in them. Let us now discuss how naive ideas of the learners can help you to explore them.

5.3.1 Naive concepts

When learners undergo an experience, they try to make its connections with the existing ideas. If it does not fit well with the existing ideas, then these ideas are altered to make connection with their experiences. That may result in the formation of misconception or naive concept.

The experience of a child is that whenever she wants to move an object, she has to apply force. Therefore, it would not be surprising if she develops a concept that when an object is static, no force is acting on it. This concept may be called a naive concept. The challenge for the teacher is to devise activities, thought experiments or arguments to confront the shortcomings in her concept and lead her to understand that forces are acting on the static object, but they balance each other and it is the net force acting on the object that is zero. In this way, a naive concept can be reformed to scientifically accepted concept.

It is important to know, how learners process the information to explore their naive concepts. Naive concepts can give rise to cognitive conflict (see section 8.11). If their naive concepts are not addressed and reconstructed, they continue to function as constraints in learning. The longer they remain unchallenged, the deeper they get embedded in their cognitive framework. You have to **catch, challenge** and **change** their naive concepts for meaningful teaching-learning. You can consider the steps depicted in the following figure (Fig. 5.1) for addressing their naive concepts.

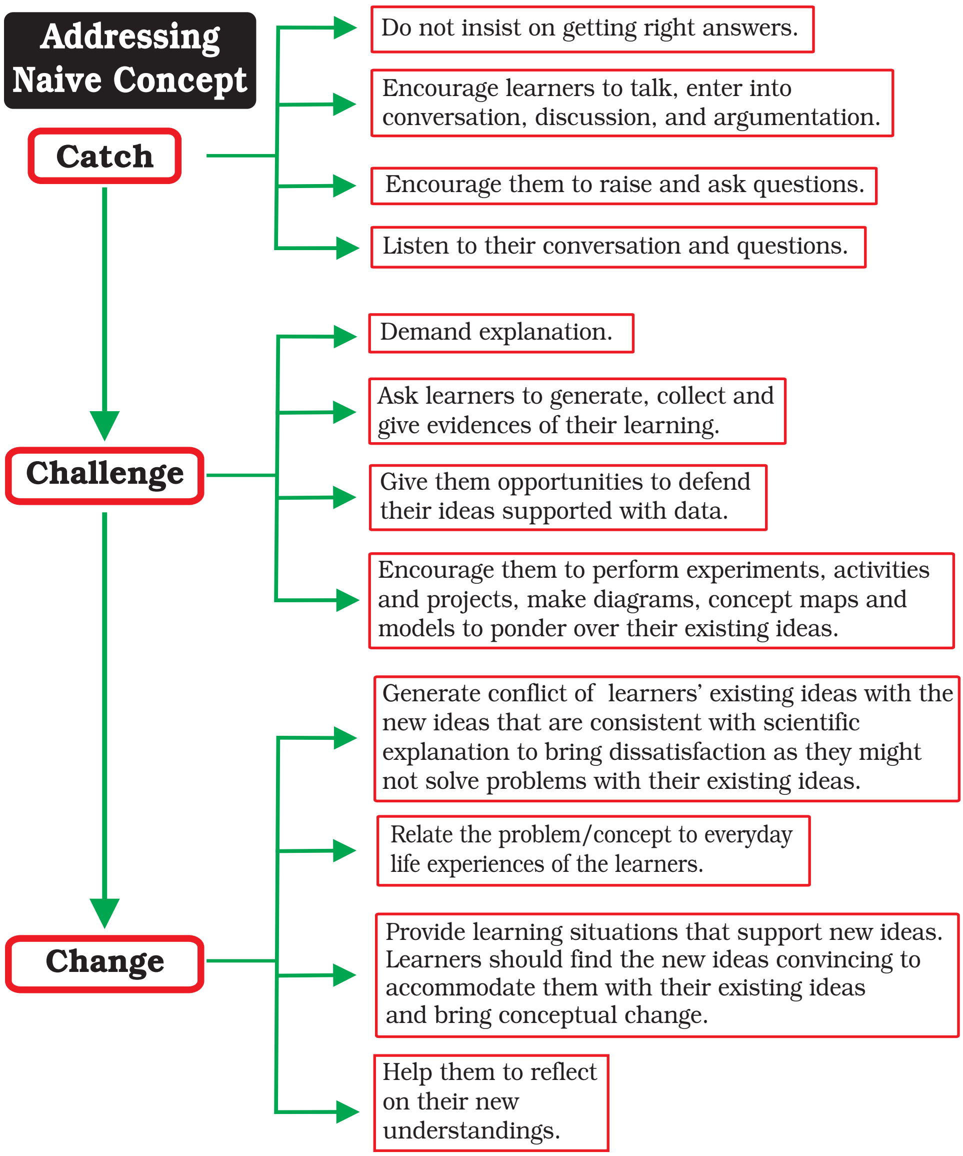


***Fig. 5.1** Addressing naive concept*

These suggested strategies to deal with the naive ideas of the learners may sound easy. However, it is a challenging task for the teacher to help learners to revisit and reconstruct their existing concepts. Therefore, at the first place care should be taken to prevent formation of incorrect or partially correct concepts by designing suitable teaching-learning experiences involving learners actively.

ACTIVITY 5.2

Some alternative frameworks of students as observed by Javed, a science teacher at secondary stage, during teaching-learning process are given below. Can you help him to identify those frameworks as misconceptions and naive concepts. Discuss how these concepts can help him to plan teaching-learning experiences for his students.

- Heat and temperature are synonymous.
- The sensation of coldness is due to transfer of cold towards the body.
- A substance which is a good conductor of heat will necessarily be a good conductor of electricity.
- Batteries have electricity inside them.
- Change in season occurs due to changing distance between the earth and the sun.
- Electrons move with the speed of light inside a conductor when electric field is applied.
- Adding oxygen in a reaction is oxidation.
- A chemical reaction continues until all reactants are exhausted.
- The bubble in boiling water consists of oxygen or air.
- Ice is always at zero degree Celsius.
- Moon changes its shape.
- Each electron physically moves in an electrical circuit from one end to the other end to constitute current.
- A chemical bond is a line or a stick.
- Carbon atom is black.

ACTIVITY 5.3

A student comes to the class with a naive concept, 'if an object has zero velocity, it has zero acceleration'. Discuss how will you deal with this naive concept and reconstruct it according to scientifically accepted concept.

ACTIVITY 5.4

Critically evaluate the statement of the teacher and the students given below and discuss with your friends how they are consistent/inconsistent with the scientific explanation.

Teacher: A horse weighs 500 kg. How much force does he have?
Student A: He has got 5000 N of force.
Student B: A horse cannot have force. 5000 N is interaction between the earth and the horse.

ACTIVITY 5.5

Think about a topic on physics/chemistry you studied in school. Try to recall what naive concepts you had got related with the topic. How did these naive concepts hinder the process of your knowledge construction in the classroom? Share your experiences with your friends.

5.4 INVOLVING LEARNERS IN TEACHING-LEARNING PROCESS

Involving learners in teaching-learning process provides a feeling of ownership in their learning. **Traditionally, it has been the responsibility of the teacher to do all the planning for teaching-learning but presently, it is considered as a shared activity between the teacher and the learners about content, activities, approaches and assessment.** Keeping themes in mind, you can interact with learners to decide what they would like to know about a particular theme. With their help you can identify the 'content' for the lesson. You can add and supplement to the 'content' selected by them. The approach of transaction can also be negotiated with learners. Learners can suggest, discuss, share information and experiences, perform experiments, go for excursion or do other activities for learning and developing deeper understanding about the concept to be learned. You can use a variety of activities, strategies and approaches to involve the learners at various junctures of learning.

5.4.1 Appreciating dialogue among peers

You should appreciate dialogue among peers in the teaching-learning process. Dialogue involves one to one interactions in the classroom among the learners. Dialogue provides space to learners to reflect on their own ideas on scientific concept. It may lead to a discussion intended to produce an argumentation. Dialogue may be structured or unstructured.

Structured Dialogue **:** It may be used by the teacher and the learners as a means of orienting the dialoguing discourse towards understanding the problems under consideration.

Unstructured dialogue **:** It may also be used as a form of discussion which may not have a desired end.

Dialogue is an important classroom tool which can be used to focus on a problem and has the potential to inculcate interest among learners and encourage them to open up for discussion and argumentation. It helps to reinforce learning by helping learners to construct collectively deeper understanding of concept and to know how the same learning experiences are perceived differently by different learners. Encouraging dialogue among peers also develops bonding among them that provides a foundation to collaborative learning, negotiating ideas and other life skills. When students are engaged in conversation about their observation, hypothesis, ideas and thinking on a particular activity, experiment, project or scientific concepts, they get an opportunity to know one another's perspectives on the concerned issue, make connections with their prior learning and get the key points. They co-construct the meaning and learn how to express their opinions. However, guidance of the teacher is necessary to help them remain focussed on the issue.

Savita, a higher secondary school teacher encourages her students occasionally to exchange a brief dialogue during teaching-learning on physics. She initiates it with an open-ended question or an experiment. She then allows them to discuss and share their ideas with their classmates. Students express themselves orally and sometimes 3–4 students together note down their ideas with different ink colours on a sheet of paper. They enter into a dialogue on the concept by writing on the paper. Moving around in the classroom, she observes the dialogue sheet to identify the depth of understanding of individual student as well as common trends in the emerged learning. It helps her to understand students' way of thinking and to analyse the teaching-learning process. It also actively engages students in constructing meaning through participation, listening, analysis, and interpretation. She says, "my students look forward to this type of activity as it provides a break from the routine classroom events".

In the process of dialogue the teacher empowers the learners through conversation and questions to build their own understanding and to learn to think analytically. Teacher can ask her own question in response of student's questions rather than simply providing readymade answers to them to keep the dialogue rolling on. It can encourage learners to get an insight for interconnectivity of various concepts. Learners can examine and analyse the concepts from multiple points of view from the social interactions in the classroom. The teacher should facilitate the learner to listen to her classmates attentively without interruption and to use sensitivity to take her turn to express her ideas.

Angela, a teacher is transacting the concept 'what dissolves in water and what does not' in Class VII. She forms small groups of students and asks them to see themselves which of the following materials dissolve in water.

- Sugar
- Salt
- Iron filings
- Coffee powder
- Wooden shavings
- Lemon juice
- Mud/Sand
- Sharbat

She helps the students to think about the following questions and discuss among themselves in groups.

Q.1 Which of the substances in the above list dissolve in water?

Q.2 What happens to a substance when it is dissolved in water?

Q.3 Try to dissolve four teaspoonful of sugar in a glass of water. Observe the level of water. Does it rise?

Q.4 Do you see some undissolved sugar at the bottom? How can you dissolve it in water?

And the list of questions goes on with students' added questions.

The students perform the activities in groups and enter into argumentation among themselves about the observations and the reasons for such observations. In the process they

- listen to other students and discuss with them;
- express their point of view justifying their statements;
- accept/reject and acknowledge other student's point of view;
- make other students understand their point of views; and
- mutually arrive at the correct reason.

They interact with the teacher and students of other groups to arrive at scientific explanations and conclusions. They share their observations. Each student learns with a little help from her peers.

Obviously, knowledge is being constructed by learners through social interactions in the class and this knowledge is shared among the learners. It is important that teacher should remain vigilant, so that dialogue does not lead to wrong conclusion. She should intervene at critical juncture to guide the conversation, so that it leads to scientifically consistent explanations.

Lev Vygotsky (1896–1934) believed that, “Children undergo quite profound changes in their understanding by engaging in joint activity and **conversation with other people**.” He emphasised that learning is a complex activity. Learners learn a lot when they interact with their environment. Environment refers not only to school and physical and social surroundings, but also to their peers, the teachers and parents. Therefore, meaning is constructed not only through processes operating on ‘individuals’, such as the stimulation of senses or the mediation of prior knowledge, but also through processes of social communication. Learners should be encouraged to learn from each other, be it dialogues, small group activities, cooperative or collaborative learning. This is essential for holistic development of the learner.

ACTIVITY 5.6

Assume that a peer group of 7–8 B.Ed. students of your class are Class VIII students. Discuss with them on the topic *Global warming and its influence on us.* As a teacher, what role will you play to ensure that your students are learning through such interaction among themselves and with you?

The process of dialogue can be followed by generating discussion in the class by emphasising on argumentation in science, highlighting the importance of learning from social interaction in the classroom and the role of learners in negotiating and mediating learning in physical science.

5.4.2 Generating discussion

Discussion is an important process of learning and understanding our environment. It is a way of putting our point of view and supporting it through convincing information, arguments and evidences. Discussion is required to acquire scientific and technological knowledge and to understand the physical and social environment around us. Therefore, teaching-learning of science should encourage the learners to generate discussions and question about the world around them.

Many a times the term discussion is used for any type of oral interaction. For example, when a teacher says, “let us discuss on the *conservation of momentum”* and asks a few questions to the class about the content without providing the learners the space for raising and asking questions, performing activities, doing investigations, solving problems, interacting with peers and surroundings— it is not discussion and has little learning value.

Generating and conducting discussion for active participation of the learner require the following:

- Selecting suitable concept or topic which interests learners. Learners maybe involved in this.
- Creating situations like activity, experiment, project, video clip, learners' report, field trip, etc. It can provide a common platform to the learners for class discussion.
- Ensuring participation of all learners. When you plan discussion based on the activity or experiment, arrangement of materials and apparatus should be such that each learner may obtain, perform and return the materials herself with a minimum disturbance to the classmates.
- Encouraging the learners to put their questions as well as to response to other's questions or viewpoints with suitable reasoning and argument. Probing questions asked by the teacher seeking explanations and reasoning can foster critical and creative thinking in learners.
- Acknowledging and praising learners for their responses, adding and supporting their ideas, identifying knowledge gaps without criticising them can help them to sustain their interest and keep the discussion rolling on.
- Summarising, reviewing and evaluating the ideas with the help of learners at the end of the discussion.

When students plotted displacement-time graph for a moving object (say, a car) Satinder, a teacher at higher secondary stage generated discussion around following questions:

- What type of motion is represented by the graph (Fig. 5.2)?

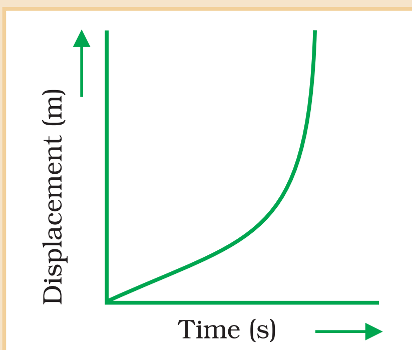


Fig 5.2 *Displacement-time graph for a moving car*

- Is it an accelerated motion?
- Can we find velocity of the car at any instant of time from the above graph?
- How can we draw velocity-time graph using the above graph?

Such situations can encourage learners to consider multiple views, reflect on their own and other's views using their thinking and existing ideas. Though it is not possible to anticipate all questions of the learners in the class, framing few questions or identifying some points on the concerned concept or topic beforehand helps the teacher to remain focused on the issue during discussion.

You can initiate a discussion by giving a 'statement' or 'posing a problem' or putting a question in situation where you expect varied experiences and understanding to exist among the learners.

Martha had to transact the lesson on *Is matter around us pure* to the students of Class IX. She framed following questions for generating discussion:

1. Why do we need a water purifier?
2. What does a purifier do?
3. What do you mean by purifying water?
4. What other substances do you think are 'pure'?
5. What do you say about pure air? Do we get pure air to breathe?
6. What do scientists mean when they say, 'a substance is pure'?

She displayed the pictures and samples of the brand names of water purifiers in the class. Holding a glass of tap water in her hand, Martha engaged students in discussion.

Martha : How can you convert the water in this tumbler into 'pure water'?
Student A : We can purify this water by boiling.
Martha : How can boiling purify the water?
Student A : By killing germs in the water.
Student B : By exposing water to the sunlight. It will kill bacteria.
Student C : How long we should keep it in the sun to purify? What if sunlight is not available during rainy season? Better, we can purify water by adding chlorine to it.
Student D : By adding alum. My mother puts some alum in water container at home.

Students started discussing various methods of purifying water by raising questions, giving arguments and appreciating ideas of their peers.

Martha listened to them patiently and proposed to the class 'Let us perform one of the activities.'

Martha : What will happen, if we heat/boil the water?
Student A : Water will be converted into vapours.

Martha facilitated students to heat the water in a beaker till it started boiling. Students observed that vapours were moving into air.

Martha : How can these vapours be collected?
Student B : We can collect the vapours by placing a plate over the beaker.

A student placed a plate over the beaker and observed. Water vapours got collected on the inner side of the plate and condensed into water droplets.

Student C : We are getting water back from vapours.

Martha : What do you think about this water?

Student A : It is pure water. Is it suitable for drinking?

Martha : It is not unfit for drinking, however, it lacks taste due to absence of essential mineral salts. Water purifiers used at home do not remove essential mineral salts. Only harmful bacteria and substances are removed. The treated water is suitable for drinking.

Martha helped students to form the concept— 'pure'. Students came up with a number of definitions of pure substances and examples like pure *ghee*, pure *milk,* etc. Through discussion she helped them to arrive at the conclusion that most of the matter around us exists as a mixture of two or more pure components. She suggested them to make a list of substances which were not pure but 'mixture' which they used and saw around them. Students were encouraged to collect as many mixtures as they could from their surroundings. It helped them to clear their concepts and develop understanding about the things they saw, knew and experienced in their daily life. She then encouraged students to separate the contents of the mixtures given below:

- Salt in water.
- Sand in water/clay in water.
- Iron pieces in junk.
- Junk of waste material - from kitchen/home.
- Tea with leaves.
- Oil and water, etc.

During this activity and discussion Martha facilitated students to develop the concepts on *solution, homogeneous and heterogeneous solution, suspension, sediments and filtration.*

Generating discussion is one of the powerful ways to lead the learners into inquiry and learning to learn. Discussion may be generated in order to predict, explain and interpret the result of activities and experiments, solve problems and plan future teaching-learning activities. A good discussion allows free exchange of ideas amongst all learners and the teacher in the class. Learners get opportunities to listen, support criticise, argument and evaluate other's ideas. Learners put forward their point of views and experiences. These help in the development of open-mindedness and ability to suspend judgment until convinced by arguments presented by others. Let us now see how learners can be involved in argumentation in teaching-learning of science.

ACTIVITY 5.7

Select a topic from the textbook and identify the situations to generate discussion in the classroom. Identify the points/frame few questions around which you will facilitate discussion in the class. Discuss your ideas with your friends.

5.4.3 Argumentation in science

Argumentation is the process of doing argument. Argument is a form of discussion that needs to be planned through suitable learning experiences. It plays a vital role in science education. It helps building of explanations, models and theories in science and promotes learning. **Argumentation in science provides the learners an opportunity to generate, collect and use evidences to make sense of the concepts being studied.** Learners critically evaluate each other's claim and evidences.

- It provides opportunity to the teachers to explore ideas of the learner in a social set up by engaging her in justifying, defending, collecting evidences, doing experiments and activities, critically evaluating evidences.
- It develops communication skills of learner. Learner learns to use scientific vocabulary and scientific concepts to support her arguments.
- It discourages learner to accept science as a mere collection of facts and accepting passively the provided explanation of natural world as right or wrong.
- It helps the teacher to know about thinking and learning process of the learner.

Generally, the most frequent type of questions that is used by teachers in science classroom demanding fixed responses, do not encourage students to share their ideas or enter into interactive discourse. It is observed that there is a direct relation between open-ended questions and increased involvement of learners in argumentation. **When learners are given opportunities to voice reasoning to their knowledge claims and throwing them to be evaluated by the peers and the teacher, they learn about constructing as well as evaluating arguments and making sense of their own knowledge.** Learners then view themselves as the constructor of knowledge and teacher as a *facilitator of learning* rather than a *knowledge dispenser.*

Role of teacher in promoting argumentation

Just giving learners scientific or controversial scientific issues to discuss will not ensure argumentation and valid learning. Following considerations can be made in teaching-learning of science:

- Provide an open-ended situation to the learners to initiate argument.
- Use arguing prompts to motivate learners to participate in the argument. Some of the arguing prompts can be:

– How can you explain the observation?
– Why do you think that way?
– What do you think about the reason for your answer?
– Can you think of another argument for/against your view?
– How do you know what you know?
– What is the evidence of your knowledge?

- Ensure homogenous participation of learners in argumentation.
- Intervene in the argumentation when the objectives of learning are not being achieved directly or indirectly or the argument becomes unharmonious or unhealthy.
- Provide positive feedback to the learners.
- Help the learners to summarise the major ideas evolved in argumentation at the end.
- Suggest further follow-up activities to ponder over the argument further.

The teacher is discussing on the topic *How do we see*?
Students interact on this concept with each other and with the teacher.

Student A	:	We see light, because rays travel from our eyes onto the object.
Student B	:	But our eyes don't produce light. Eyes are just organs for vision.
Student C	:	Yes, our eyes are not source of light. If they would have been, we could see the objects in the dark also.
Student B	:	Yes, it means that our eyes alone cannot see any object. We need light to see.
Student D	:	I think it is correct. If there is no light we cannot see anything.
Student A	:	That means when light enters our eyes from the object, we can see the objects.
Student B	:	Light enters our eyes when they are emitted from a source.
Student C	:	But, we can see each other. We are not a source of light. The light entering our eyes might have been emitted by the object or might have been reflected by it.
Teacher	:	Yes, that is right, light is needed to see. We can see an object when light is emitted or reflected by it and enter our eyes.

This is a sample of argument that makes students participate in interactive learning. You can see how students are giving reasoning and justifications. Teacher can initiate and sustain argumentation for learning science by discussing on common observations. Space should be given for reasoning, evidences, justification, open ended questions, experiments and investigations, analysis and interpretation of data. Thus, argumentation includes coordination of evidence and theory to support or refute a task related with knowledge. Argumentation in science can be supported by the observations based on activities and experiments, discussion based on mathematical formulations and using sentences with scientific vocabulary clearly and logically. **Introducing argumentation in the classroom requires a shift in the role of teacher from authoritative to a dialogue approach associated with extended contributions of learners.** Argumentation in classroom helps to construct knowledge, clarify concepts, remove naive concepts and make learners active partners and become self aware of their learning.

Many of Suresh's students complain that they get confused with several erroneous arguments given by other students in the class. He makes counter argument to them by mentioning that judging the validity of arguments is a skill highly valued by scientists.

ACTIVITY 5.8

'A concave lens always gives a virtual, erect and diminished image, irrespective of the position of the object.'

Student A argues that this statement is correct, because it is given in the book.

Student B argues that this statement is correct, because her teacher has told this.

Student C manages to get a concave lens from the school laboratory. Taking a cancave lens, a candle and a screen she performs an activity to test out the above statement.

She argues that the above statement is correct, because she has got evidences of it. Discuss in the class:

(i) Whose argument is scientific?

(ii) Is it feasible to give evidences of all facts and observations given in the book? If yes, explain how.

(iii) Is it feasible to carry on argumentation on almost any concept? Discuss with your classmates. What consensus do you arrive at?

5.5 ROLE OF LEARNERS IN NEGOTIATING AND MEDIATING LEARNING IN PHYSICAL SCIENCE

Manju is discussing the topic 'pH scale' in Class X. During the lesson she discusses the concept of pH, variation of pH with the change in concentration of H+(aq) and OH-(aq) ions, pH of some common substances and mathematical interpretation of the scale. Students perform some activities to observe pH of acids and bases. After the transaction of the concepts she distributes the following questionnaire to her students.

1. Did you find the discussion on pH scale in the class interesting? Give your suggestions.
2. What are some questions regarding pH scale that still remain unanswered?
3. What other matters regarding pH scale do you want to discuss in the class?

4. Which other activities you would like to do in the class regarding pH scale?

   Manju observed the students' responses as follows.

   - Students found the topic quite relevant and exciting.
   - They wanted to find pH of
     - rain water (to test if it is acidic);
     - water of the river in their city;
     - milk and other household liquids;
     - their saliva after eating salads, rice, soft drinks;
     - their saliva in the night after brushing the teeth and in the morning before brushing;
     - an antacid solution; and
     - extracts of various flowers and leaves.
   - To find pH of liquid effluents discharged in the river at various places from various sources, they wanted to conduct a visit in small groups.
   - What happens to pH value when an acid is diluted 10 times, 20 times, etc.?
   - Is the pH of dilute acid less than its concentrated form?

After receiving inputs from the students, the teacher planned her further course of action. She organised a field visit for them and also helped them to work in laboratory. She gave them a list of references for self study and supported them when required. Students worked enthusiastically on pH scale. Some of them took up this topic for their project work. A few students collected videos on pH and explored further activities.

Thus, the students' opinions in the process of learning enriched the teaching-learning process.

The mediation of students helps the teacher to design relevant activities according to the need of the learners. The learners develop a sense of involvement and participation in the teaching-learning process. Learners negotiate what they will learn, how they will learn within the given framework of the curriculum.

Bhupender had just completed the chapter on *Electricity* in Class X. He was planning for an assignment on *Energy Conservation.* He discussed with the students about the activity they would like to do to work on a project on energy conservation. Students came up with a number of ideas, such as making presentations, doing surveys, making energy audit sheet, calculating energy consumption by various appliances at home and at school, making pamphlets and posters, organising puppet show and enacting a play for spreading awareness about conservation of energy.

He then allotted the various activities to the students, roll number wise, and asked the students to submit their project work after five days.

The students looked dismayed, some because they felt that they wanted to do some other activity and not the one allotted to them. Some other found the time given for preparation was too little.

He played his role with patience and consideration. The students swapped their activities as per their interest and capability. Then they literally bargained for time. They complained about the load of assignment of other subjects and the impending annual sports day. The teacher then decided to spread out their submission dates in a span of ten days, but took a promise from the students that they would not delay it further. Students formed small groups and started working on the project. The teacher intervened, wherever required.

This negotiating session gave a sense of ownership of learning to the students. It made learners the centre of the teaching-learning process. It also helped the teacher to explore the learning evidences of the learners and remove any discontentment that they might have had otherwise.

Following are the positive points of learners' negotiation and mediation in learning process:

- Learners become active partners in learning. It generates interest in learning science.
- It raises self-esteem, critical thinking and listening skills of the learners.
- They design activities with the help of the teacher. Thus they learn by doing themselves.
- They feel responsible for their learning. The whole learning process imparts a sense of achievement and satisfaction.
- They work in collaboration with other learners and teachers, and develop various social skills.

Teacher should create a learning environment in the class that is conducive for mediating and negotiating learning in the pursuit of learners' questions rather than strict adherence to the curriculum. Learners can mediate and negotiate in a collaborative set-up that can influence their actions. Learners can compare and contrast their ideas, attempt to integrate information from two or more sources such as observations of two similar experiments to mediate and negotiate learning and construct their knowledge. In the context of physical science, there is little scope for compromise as indicated by the words *negotiate* and *mediate* in isolation. Learning tasks in physical science may be performed differently, argumentations may be given differently, however, meaning can be obtained by mediating and negotiating with peers and the teacher. Opportunities of observations, discussion, argumentations and presentations can be given to the class as a whole. Negotiation is reached when a learner believes that her construction of knowledge and its scientific explanation are not different from her peer's even though they are likely to be different. The role of the teacher is to act as a facilitator of learning, encouraging interventions and promoting learner's autonomy.

ACTIVITY 5.9

Develop a questionnaire on the topic *oxidation and reduction* so as to know what your students might like to learn and what activities they might perform to know further about the concept. Discuss with your friends the plan how you will facilitate students to achieve their learning needs.

You may argue that involving learners actively in the teaching-learning provides little time for the teacher to cover the contents of the syllabus. However, this gives learners time for critical thinking. This places more responsibility of learning on the learners and they come prepared in the class. It also brings readiness for learning in them. Active engagement of the learner needs proper planning and patience on the part of the teacher in the beginning. It saves your time and effort in the long run as it leads to deeper understanding, setting the learner on the path of meaningful learning. You would not observe more misconceptions and naive concepts in learners.

5.6 ENCOURAGING LEARNERS TO RAISE AND ASK QUESTIONS

If you take a round of the corridors of traditional schools running the classes, most of the time you will hear the voice of the teacher. Even if students are speaking, they are answering the questions that the teacher asked. Opportunities are seldom provided to students to raise and ask questions. NCF-2005 recommends that teachers need to nurture an enabling learning environment in the class where children feel secure, there is absence of fear, and which is governed by relationship of equality and equity. Often this does not require any special effort on the part of the teacher, except to practise equality. The classroom space should have a favourable climate where children can ask questions freely, engage in dialogue with the teacher as well as with their peers during an ongoing lesson. Unless they can share their concept-related experiences, clarify their doubts and ask questions, they will not engage with learning. If instead of ignoring children's comments or sealing their tongues with strict rules and restricting on the language to be used, teacher encourages them to talk, they would find that the classroom is a more lively place and that teaching is not predictable and boring. It then becomes an adventure of interacting minds. Such an environment will facilitate the self-confidence and self-esteem of learners of all ages. It will also go a long way in improving the quality of learning itself.

Asking Questions

'Air is everywhere' is a statement that every school child learns. Students may know that the earth's atmosphere consists of several gases, or that there is no air on the moon. We might be happy that they know some science. But consider this exchange in a Class IV classroom.

Teacher: Is there air in this glass?

Students (in chorus): YES!

The teacher was not satisfied with the usual general statement, 'Air is everywhere.' She asked the students to apply the idea in a simple situation, and found, unexpectedly, that they had formed some 'alternative conceptions'.

Teacher: Now I turn the glass upside down. Is there still air in it?

Some students said, 'Yes', others said, 'No', still others were undecided.

Student 1: The air came out of the glass.

Student 2: There was no air in the glass.

In Class II, the teacher put an empty glass over a burning candle and the candle went out!

The students had performed an activity whose memory had remained vivid even two years later, but some of them at least had taken away an incorrect conclusion from it.

After some explanation, the teacher questioned the students further—Is there air in this closed cupboard? Is there air in the soil? In water? Inside our body? Inside our bones? Each of these questions brought up new ideas and presented an opportunity to clear some misunderstandings. This lesson was also a message to the class: do not accept statements uncritically. Ask questions. You may not find all the answers, but you will learn more.

— *NCF–2005*

Science involves observation, investigation and inquiry. **Asking questions is one of the most valuable skills a learner can have for learning science.** Learning process should lead to a situation where the learner gets involved in cognitive conflict. Studies show that students find the class boring if only teacher asks questions and they are not allowed to express their ideas. In the class learners ask mostly those questions that relate what they are learning in the school with the things outside the school. In this process many questions may come up to their mind. They should be explicitly encouraged to raise and ask questions.

5.6.1 Strategies to encourage learners to ask questions

- Welcome and value each and every question. No question should be stamped as simple or silly question.

Teacher asked, what are the three different forms of water? A student replied, *water, jal and pani.* All the students in the class started laughing. The child felt embarrassed. Teacher looked at the class silently for a second and said, "I never thought that way." There was silence in the class for a few seconds and then the same student replied, "*ice, water and water vapour.*" The teacher then appreciated the student for venturing an answer and told the class that if students remained silent for fear of being laughed at, they would not learn much. Speaking out is better than silence.

- Even if the question is simple or silly, it should not be tagged as such. Instead, learner should be guided to search the answer by asking some probing questions based on her previous experiences.
- Acknowledge their questions as *very good; interesting; intelligent questions; good statement; your question shows, 'you are thinking;' 'you are creative;' 'you have read a lot*;' or with similar feel.
- Only a few students should not be allowed to dominate the class. Provide equal opportunities of interaction to all. Students and teachers together may set a rule with respect to interaction. It may be *each learner of the class has to raise at least one question during teaching-learning process of one chapter/unit.*
- Familiarise them with the fact that asking a good question requires thinking and knowledge. Not only their answers, but also the quality of their questions will be assessed in the class. This would motivate them to concentrate on learning and thinking.
- In spite of having a good social and emotional climate of classroom, you may find that a few students are hesitant in asking questions. You may need to be empathetic with them. You may say, *I understand. Even today I sometimes find difficult to ask question in meetings, but I have observed that once I start getting involved in conversation, things become normal and easy.*
- When you set up a difficult problem and do not get any response from the class, you may provide hint or draw their attention to the difficult part of the problem to encourage them to think and raise questions. You may speak in lighter tone, *perhaps I explained it very quickly; I will discuss it again;* or, *this type of problem we have not done in the class earlier; do not give strain to your brain; take your own time; we shall discuss it tomorrow; etc.* Learners should be made to realise that

learning science is not difficult, if they understand the underlying concepts.

- Instead of providing readymade answers to learners' question, the teacher should provide situation or experience so that they can get the answers themselves. You can pass on the question to different groups of learners. Let them enter into a dialogue with one another and then facilitate them to arrive at the answer.
- When you observe that the same question is raised by many learners of a class or one learner asks the same question many times, you need to reconsider the strategies of your teaching-learning. You may say, *sometimes I move from one concept to another concept very fast.* These types of statements will help the learner to save her face and she will not feel hesitant in asking questions in future. Statements like *listen carefully to what I say; you are not attentive; I have explained it several times,* should be avoided.

Teachers should not insist that all learners in her class must give identical answers to her questions. Instead she should encourage students to ask as many questions as they can, related to the activities going on in the classroom, and also search for the answers on the basis of their own observations and experiences and information including the one they get through the media. They should be encouraged to express themselves in their own words from their own experiences.

Learners may ask questions not only during transaction of a concept but also when involved in any teaching-learning experience. Let us see the following example:

Sameer and Savita are students of Class VI. Their class teacher, Mayank has announced the date for a trip to the Science Centre. As soon as students came to know about this, they became excited and started asking lots of questions. The teacher facilitated them to put their questions one by one. Their questions were— At what time we will leave? How far is the place? How shall we go there? How long will we stay there? Can we bring special food items for our lunch? Do we have to write something there? Should we bring our school bag? Can we take pictures there? Do we have to come in school uniform? Will there be shops outside? Can we bring money for buying anything? Do we have to make the record of activities and materials displayed there? Can I bring my sister along with me? And so on. The teacher patiently listened to all the students and helped them to arrive at a consensus. It gave them a sense of belongingness to the teaching-learning situations.

Mayank believes that no question is wrong or irrelevant. He always encourages his students to ask question. Here you can notice that many questions are not relevant, but the teacher did not stop them.

ACTIVITY 5.10

Do you ask questions in the class? Observe and note how frequently you and your classmates raise and ask questions to your teacher-educator during teaching-learning process and how do those questions support teaching-learning in the class.

5.6.2 Creating the habit of listening to learners

Asking and listening are closely tied together in teaching-learning process. You can listen to students by asking questions or presenting an open-ended question or problem or conflicting situation or asking a battery of questions. Listening to students is one of the most powerful tools of teachers in order to

- know what students think about certain scientific phenomena;
- understand why students think that way;
- find if their thinking is consistent with the scientific explanation;
- gauge how logically they think;
- find how do they apply their understanding of concepts in explaining a scientific phenomenon or a new situation;
- find if there is a learning gap between their thinking and existing concepts of science; and
- know how do they organise their thoughts about scientific concepts and express themselves.

While listening to your learners, be focussed on what the learners say, do not agree or disagree or be judgmental. Let the ideas first flow. You may respond non-verbally occasionally. Your body language should encourage the learners and convey that you are listening.

5.6.3 Creating opportunity of listening to learners

- **Acknowledge the fact that each learner is unique with varied levels of interest and abilities.** Learners come from a diverse social and educational background. Each of the learners may respond differently to the same learning situation. Also each learner is capable of learning, but you need to be aware of her existing ideas to motivate her in learning.
- Take the time to observe and assess the ideas of all learners including those seemingly invisible students who seldom participate in teaching-learning process. Listen to their explanation of scientific concepts. You will be aware of the complex way of thinking that might give you an insight into choosing an appropriate approach to teaching-learning.

Gurmeet took a few drops of spirit/petrol in a watch glass. She helped students to observe what happened to it after a few minutes. She asked,

- What is happening to the drop of petrol?
- Where has it gone?
- Why? Can you explain?

Observing this simple activity, a number of questions came up from the class.

- When we put a drop of water on the watch glass, it does not vanish so quickly. Why?
- What do we call this phenomenon?
- Do the molecules of petrol still exist?
- Where do they exist now?
- In what form do they exist?
- Do the petrol drops exist in some chemical form?
- What might be its new chemical composition?
- When it is placed in a closed bottle, it does not disappear, Why?

She first listened to their explanations, without being judgmental and then facilitated them to get scientific explanations.

Next time, students performed an activity by sprinkling iron filings near a magnet. They observed that the iron filings align themselves along a particular pattern. Some students repeated this activity by using another magnet. They observed the pattern of alignment to be the same.

She then invited her students to ask as many questions as they could regarding the activity. This helped her in understanding thinking pattern of the students regarding various concepts of magnetism. She allowed students to interact in a group of three for 10 minutes. Meanwhile she was moving around the class to listen their informal talk and discussion. She called one student on the blackboard to jot down the questions asked by students. She observed that many questions were repetitive. Students of different groups volunteered to answer many questions. She facilitated them to summarise the explanation after listening to her students. Questions asked by students were as follows.

- Why do iron filings arrange themselves by making a design on the paper?
- Why do iron filings form line-like pattern?
- What does the pattern of iron filings demonstrate?
- Is there some specific name of these lines?
- Do all magnets form a design with iron filings?
- Why are more iron filings stuck near the ends of the bar magnet?
- What pattern would we get if magnet is placed vertically over the board?
- Will it form any pattern with talcum powder, salt or black pepper powder?
- Why does magnet not make pattern/design at points far off from it?
- Do iron filings get magnetised?
- How would the patterns of iron filings be disturbed if magnet is removed from the paper?
- Is there any other method of obtaining this type of pattern around a bar magnet?
- Where is the maximum strength of magnet?
- Why do we observe magnetic field lines?

Children are curious by nature; observing any novel situation or thing they become impulsive to ask questions. Pin drop silence in the class is not conducive to learning. **Science classroom environment should be conducive for generating curiosity and thinking, so that learners get motivated to talk over the issue, ask questions and enter into discussion and argumentation. Every question of each child should be respected.**

Rita has kept a question register in her class in which few pages are marked for each chapter of the science textbook. She has directed her students to write the questions in the register on the pages marked under the particular chapter. She goes through these pages regularly. Later she discusses with her class. If need arises, she designs activities also with the help of her students.

ACTIVITY 5.11

Select any topic from the textbook and discuss with your friends. How can you create opportunity to listen to learners during teaching-learning of this topic?

There is no hard and fast rule by which you can generate situations for listening. If you ask formal questions, answers to which may be given by 'yes' or 'no' only, you will not get much opportunity to listen to your students. You need to pose open-ended and thought provoking questions that may help learners in interpretating information, predicting consequences, making inferences and thinking critically.

5.7 ENCOURAGING LEARNERS TO COLLECT MATERIALS FROM LOCAL RESOURCES

We know that children learn or construct their knowledge on the basis of the experiences they gain through observation and activities they are engaged in outside and inside the school and home. It is reiterated that with proper planning of activities involving learners, a teacher can awaken their interest in learning science. Learners get opportunities to establish link with their previous experiences and for context-based learning by getting involved actively.

Suresh, a secondary school teacher plans activities of the chapters on science with the help of his students. Students identify the materials or apparatus required to perform all the activities given in the chapter. Different groups of students take charge of different activities. They collect materials from their surroundings and school laboratories with the help of the teacher, before lesson on the chapter is started. Students remain enthusiastic to learn the concept by performing activities from the collected materials and they develop a sense of achievement. It makes the teacher's work easier and the lesson interesting.

You can provide many situations where learners can collect materials, learn and enjoy learning. Some of the activities are as follows.

- Developing a science corner in the school.
- Opening science club in the school.
- Organising field trips.
- Arranging for bulletin board or wall magazine.
- Maintaining a scrapbook.
- Taking up a project.
- Making static and working models.

For developing a science corner in the school, you can encourage learners to collect materials such as coloured stones, metallic wrappers, sheets and wires, spring balance, torch cells, small tumblers and bottles, droppers, syringes without needles, small bulbs used in torches, thread, balloons, sieves, beads and thread, sticks or sipper of cold drinks, ice-cream cups and spoons, straws of different radii and many other things that can be used in making models, doing an experiment or just to study. Learners may collect different samples of soil, water, rocks, fibre, fabric, toys and materials made using magnets, stamps with pictures of scientists, etc. An exhibition of the materials collected along with proper write-ups can be organised in the school to motivate them.

Learners can also collect some materials when they go out for excursions, field trips or visits to some places. They can use the collected materials in performing activities in science club. To develop the habit of reading, learners can be encouraged to identify and collect information regarding current issues and award winners in science from various sources such as newspapers, magazines, and internet. A sense of wonder and curiosity can be generated when students see pictures given in newspapers and magazines and read about them. This can enhance their learning.

They can express their own ideas and prepare write-ups for maintaining wall magazines and bulletin boards in the school. Some learners may design cartoons or write poems, jokes and skits based on scientific concepts.

The wall magazines or bulletin boards can display theme-based information collected and displayed by learners. The themes could be from history of science, inventions, discoveries, phenomena, current issues such as global warming, floods and droughts, disaster management, volcanoes, deforestation and afforestation and many more depending on the stage and capabilities of the learners. Learners may also search and collect learning materials for virtual experiments and activities from internet. Emphasis should be given on primary sources of data and use of manipulative materials in teaching–learning of science. Learning situations emerging from some events and their observations may also be used in teaching–learning of science as it happened in the following case.

Shabnam, Atiya, Pratyush, Suhani and Akhtar read the news about Mumbai's floods caused due to choked sewer lines. They concluded that such a situation had developed due to indiscriminate throwing of garbage in the city. The disaster could have been avoided if people of the city were aware of better methods of waste disposal. They set out as a team of detectives to find out about the various types of wastes people throw out and discussed the ways to dispose the waste so as not to harm the environment. They discussed the problem of waste disposal with their friends in the school and class teacher. The class teacher converted the problem in the form of group projects on *solid waste management; land pollution;* and *water pollution* for the class.

All the above mentioned activities can generate interest in the learners, motivate them for learning and give them a chance to move out from the school boundaries and collect relevant materials and information from their surroundings.

ACTIVITY 5.12

Identify and discuss with your friend about the materials from the resources around your surroundings that can be used for performing activities, experiments and in other teaching-learning experiences.

Nadira, a secondary school teacher brought a 'curious bee' to the class. The class became very curious to observe the curious bee. She had prepared a toy which had a bed of paper flowers, each with a stem. She suspended the toy bee with a thread over the flowers, but it could not be made to 'sit' on any flower. The bee only circled around the flowers. The teacher then challenged the students to make it 'sit' on any one flower.

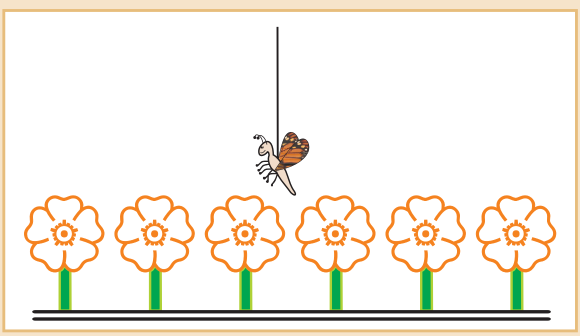


Fig. 5.3 *Curious bee: a toy*

About 8–10 students tried to make the curious bee land on the flowers by bobbing the bee up and down, but none of them was successful. Observing carefully, some of the students understood the 'curious' behaviour of the bee immediately. One student speculated about the magnets hidden in the body of the bee and the stem of the flowers. In order to transact the concept *like poles repel each other* Nadira facilitated her students to perform this activity using magnets.

She then encouraged the students to prepare different toys using magnets and materials from their surroundings. In a matter of two days, there was an assortment such as, 'chasing cars', 'unsafe purse', 'magnetic cricket', 'shooting stars', etc. based on the concept of magnet.

PSYCHOLOGICAL INTERVENTION

As far as science learning is concerned, the uniqueness of an individual student makes each one a distinct and different in terms of interest, attitude and aptitude. To understand and appreciate the uniqueness of a student, we as teachers, need to explore our learners inside as well as outside the classroom. For this, apart from usual strategies we can use a number of psychological interventions which may not only maximise their learning, but also facilitate them to utilise their wide range of potentials in a variety of teaching-learning situations. Scientific Interest Inventories; Scientific Aptitude Test, Case Studies, etc. may be used to identify the learners' genuine interest in the core as well as peripheral areas of science learning. As a teacher you must have taken cognizance of the fact that some of the learners are interested only in scientific content knowledge; some are interested in scientific procedural knowledge; some are interested in the operations, functions and applications of scientific knowledge; some are interested in the history of scientific knowledge and some are interested in the criticism of (raising questions against) fundamentals of science and scientific knowledge, etc. Thus, it is the moral duty of the teacher to nourish the genuine interests of all the students who are and will be pursuing science for different reasons at different levels of study. Any psychological intervention that you will be using must have following five basic elements.

- **Relevance:** It should be tailored to students' existing knowledge, beliefs and circumstances.
- **Individualisation:** It should be tailored to their personal needs.
- **Feedback:** It should be tailored to information regarding progress with learning or change.
- **Reinforcement:** It should be tailored to rewarding for natural urges.
- **Facilitation:** It should be tailored to providing with means to take action for learning and reduce the barriers.

5.8 SUMMARY

In teaching-learning of science, it is important for learners not only to be able to make sense of meanings and data to construct their knowledge, but they also need to be able to consider and critique others ideas. Therefore, conversation, discussion, argumentation, negotiation, mediation and listening and asking play key roles in exploring the learners. Creating learning environment through various suitably designed activities, giving value to each learner and their ideas, and understanding how they are constructing their knowledge also help the teacher to explore the learners. Eliciting learners' existing knowledge and understanding, uncovering the ideas coming to their mind and linking those ideas with suitably designed teaching-learning experiences are essential to explore learners. Active involvement of learners in all these processes are necessary to move towards achieving the aims and objectives of learning physical science.

EXERCISE

5.1 Discuss the importance of exploring a learner.

5.2 Discuss why is it necessary to identify and give value to the individual differences among the learners.

5.3 Make a list of the differences regarding learning of science you have observed among the learners during your internship programme.

5.4 Taking an example from the textbook, describe how will you motivate learners to bring their previous knowledge into classroom.

5.5 Enumerate the ways you can involve learners in teaching-learning process. Explain how can involving learners help you know about learners and their learning.

5.6 Explain how can dialogue among peer groups be used as an important classroom tool to reinforce learning. Support your answer with examples.

5.7 Select a chapter from science/physics/chemistry textbook for secondary/ higher secondary stage. Anticipate the naive concepts learners might have. How can you address them through laboratory exercise?

5.8 Search papers in science education journals related to the research on the naive concepts. Make a list of common naive concepts in physics/ chemistry. Share your findings with your friends and discuss how can those concepts help a teacher in designing teaching-learning of physical science.

5.9 How would you generate discussion through (i) an activity (ii) learner's report and (iii) learner's questions? Discuss with examples.

5.10 Critically evaluate the role of peer group conversation, discussion and argumentation in exploring learner and enriching teaching-learning process.

5.11 Explain how will you initiate and sustain an argument in the class taking examples from the textbooks.

5.12 What do you mean by negotiating and mediating learning in physical science? Discuss the role of learners in negotiating and mediating learning.

5.13 Explain what strategies would you take to encourage learners to raise and ask questions. Why is it important to listen to your learners? Elaborate with concrete examples.

5.14 How would you encourage learners to collect materials from local resources? Discuss how it can motivate them to learn physical science.

> *"To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks real advances in science."*
>
> *–Albert Einstein*

Chapter 6

School Curriculum in Physical Science

6.1 INTRODUCTION

"Science curriculum has changed over time and the job of science teacher has become more challenging now," says a science teacher. While navigating through her experiences of science teaching and learning from 1960s as a student to 2010 as a teacher, she describes the 'changes' as follows:

"I passed higher secondary examination with science and mathematics in 1969 from a school at Delhi affiliated to Central Board of Secondary Education (CBSE). We had eleven years of schooling with eight years of 'general education.' From class IX, students joined different streams namely, Science, Arts, and Commerce. There was tough competition for entering into science stream and some of my friends who were interested in learning science could not get admission to science stream. Science learning was restricted to a few elite/higher achievers. In classes IX to XI, science was taught as disciplines of physics, chemistry and biology. The books published by private publishers and written by single author were used. For students and teachers, these books were both textbooks and syllabus.Teaching–learning of chemistry started with symbols and valencies of elements. Students were taught how to write chemical formulae and how to calculate molecular and equivalent weight, write empirical and molecular formulae. The course content in textbooks contained preparation, properties and uses of gases such as carbon dioxide, oxygen, nitrogen, manufacture of nitric acid, sulphuric acid and metallurgy of some elements, etc. The practical syllabus had preparation of gases, salt analysis and acid base titrations. Learning experiences and daily life experiences remained segregated. We could not relate practical work to theory and vice versa particularly for salt analysis and titrations. Chemistry was perceived as memorisation of chemical reactions and equations. Teacher was considered as provider of information.

Now in 2011, students have twelve years of schooling with general education of ten years. Science is a 'core' subject up to Class X and it is taught as 'integrated science' in Classes IX and X. At higher secondary stages (Classes XI and XII) students study science as disciplines of chemistry, physics and biology. The syllabus of Classes IX and X has been framed on themes such as *Food, Materials, The World of Living, Moving Things, People and Ideas and Natural Resources,* etc. Students find this science more relevant and can relate it to life and surroundings. Experiments/activities related to these themes can be conducted in the classrooms. Syllabus of chemistry for Classes XI and XII has components of inorganic, organic and physical chemistry, but these have not been labelled and separated into different sections. Topics such as *Thermodynamics, Solutions, p, d and f – Block elements* reflect changes in chemistry syllabus. Now students have quality textbooks published by NCERT and written by a team of authors. These textbooks provide students space for inquiry and questioning. Activities for students have been incorporated at relevant places in the textbooks. Teacher is no more only a provider of information. Students come to class with their own experiences and lots of information and questions as they have access to information from other sources such as internet, media, variety of books, science magazines and supplementary reading materials. Sometimes a student challenges teacher's knowledge. Teachers are required to have updated knowledge and should be ready to verify and validate their own knowledge. I find my job as a science teacher very challenging. My perception of science has also changed from accumulation of information to process of creating new knowledge."

ACTIVITY 6.1

Write down your perception of science curriculum and compare how today's science curriculum is different from what you studied may be in 1980s/1990s. Discuss your perceptions and share your experiences with the class.

Above mentioned experiences of teachers may raise several questions in your mind. For example, you might ask why these changes have been made; who decides what to teach and how to teach; how curriculum is renewed and developed; what is the role of a teacher in renewal/ development of science curriculum? Answers to the questions related to decision-making in science curriculum and process of curriculum development can be found in policy documents and National Curriculum Frameworks. Therefore before proceeding further we should know the history of development of National Curriculum Framework.

In the following paragraphs we will learn about the story of development of curriculum framework in India.

6.2 HISTORY OF DEVELOPMENT OF CURRICULUM FRAMEWORK

Until 1976, Indian constitution allowed the state governments to take decisions on all matters pertaining to school education including curriculum. The centre could only provide guidance to the states on policy issues. It was under such circumstances that the initial attempts of National Education Policy of 1968 and the Curriculum Framework designed by NCERT in 1975 were formulated. NCERT developed NCF in 1975 following the recommendations of Education Policy on 1968. In 1976, the constitution was amended to include education in the concurrent list, and for the first time in 1986 the country as a whole had a National Policy on Education (NPE-1986) which envisions National Curriculum Framework as a means of modernising education. The Policy proposed a national framework of curriculum as a means of evolving a national system of education capable of responding to India's geographical and cultural diversity while ensuring a common core values and a comparable standards of education. **NPE-1986 emphasised a relevant, flexible and learner-centred curriculum.**

It recommended a common core component in school education throughout the country. The policy also entrusted the NCERT with the responsibility of developing the National Curriculum Framework and reviewing the framework at frequent intervals. Hence, in 1988 NCERT prepared the National Curriculum Framework for school education based on the recommendations of NPE-1986. After that it was felt that curriculum needs to be flexible and relevant to meet the needs of diverse learners. Also issues of curriculum load and examinations stress needed attention. Therefore, National Curriculum Framework was reviewed in the year 2000 and then in 2005 and the latest NCF-2005 appeared as a result of this review.

- NCF-1975 Following recommendation of Education Policy in 1968
- NCF-1988 Following recommendation of Education Policy in 1986
- NCF-2000 Revised NCF-1988
- NCF-2005 Revised NCF-2000

Let us now try to understand what the National Curriculum Framework is and how it leads to the development of curriculum and syllabus.

Project 6.1

Study National Policy on Education-1986, National Curriculum Frameworks developed by NCERT in 1975, 1988, 2000 and 2005 respectively. Compare the NCFs developed before and after the development of National Policy on Education and give the summary of changes noticed by you.

6.3 CURRICULUM FRAMEWORK, CURRICULUM AND SYLLABUS

Study the flowchart given in the Fig.6.1 and try to understand the relationship between the terms curriculum framework, curriculum core and the syllabus.

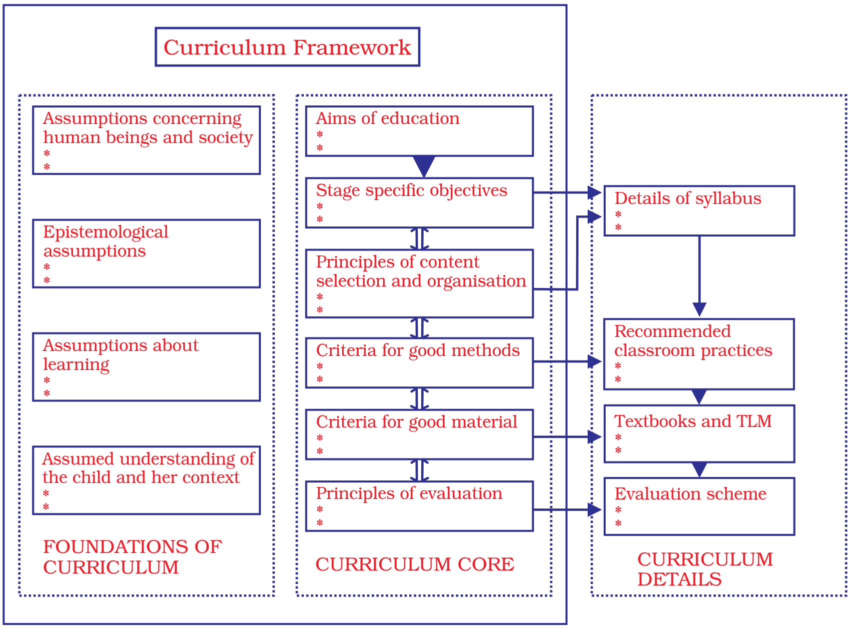


Fig. 6.1 *The graphical representation of curriculum framework*

6.3.1 Curriculum framework

From the above flowchart (Fig. 6.1), it is clear that curriculum framework is a plan that interprets educational aims vis-a-vis both individual and society. This plan leads to an understanding of the kinds of learning experiences that schools must provide to children.

The plan addresses some basic questions like:

- What educational purpose should the school seek to achieve?
- What educational experiences can be provided to achieve these purposes?
- How can these educational experiences be meaningfully organised?
- How can we ensure that these educational purposes are organised?

Thus, NCF relates to all those who are concerned with education viz. students, teachers, teacher educators, policy makers and public at large.

In India, NCERT develops National Curriculum Framework which provides guidelines for developing syllabi and textbooks and school curriculum. NCF-2005 prepared by NCERT discusses a wide range of issues concerning school education. The framework discusses aims of education; epistemological assumption about nature and forms of knowledge; and assumptions about learner and learning. It places learner at the centre and gives primacy to voices and experiences of learners. The framework views that knowledge is evolving in nature and is created involving learners as active participants in the process of knowledge construction. NCF-2005 recommends curricular areas to be taught at different stages of school education. The NCF-2005 also recommends that Arts education and Physical and Health education should be made curricular subjects at elementary and secondary stage and optional subjects at higher secondary stage. It also discusses the objectives and pedagogy of these subjects. It recommends that assessment of learner should be made an integral part of school life. It also discusses the necessary systemic reforms including examination reforms and teacher education reforms to achieve the aims of education. Some discussion about enabling school environment is also given in NCF-2005.

NCF-2005 reiterates the recommendations of National Policy on Education (NPE-1986) that contains, as has already been discussed, the common core along with other components that are flexible (see the following box).

The National System of Education will be based on a National Curriculum Framework which contains a common core along with other components that are flexible. The common core will include the history of India's freedom movement, the constitutional obligations and other content essential to nurture national identity. These elements will cut across subject areas and will be designed to promote values such as India's common cultural heritage, egalitarianism, democracy and secularism, equality of sexes, protection of environment, removal of social barriers, observance of small family norms and inculcation of scientific temper. All educational programmes will be carried on in strict conformity with secular values. India has always worked for peace and understanding between nations, treating the whole world as one family. True to this hoary tradition, education has to strengthen this world view and motivate the younger generations for international cooperation and peaceful coexistence. This aspect cannot be neglected. To promote equality, it will be necessary to provide equal opportunity for all, not only in access but also in the conditions of success. Besides, awareness of the inherent equality of all will be created through the core curriculum. The purpose is to remove prejudices and complexes transmitted through the social environment and the accident of birth.

—National Policy on Education–1986

6.3.2 Curriculum

It is perhaps best thought of as sum total of all deliberately planned set of activities which facilitate learning and which are designed to implement specific educational aims. It is a plan to explain what concepts are to be transacted and what knowledge, skills and attitudes are to be deliberately fostered. It includes statements of criteria for selection of content, and choice of methods for transaction of content as well as evaluation. It is concerned with

- the general objectives of education at a particular stage or class;
- subject-wise learning objectives and content;
- course of studies and time allocation;
- teaching-learning experiences;
- teaching-learning aids and materials; and
- evaluation of learning and feedback to learners.

In reference to the discussion given above, it would mean that curriculum core and syllabus put together form the curriculum. Thus, curriculum is a plan to develop capabilities that are likely to help achieve the chosen aims. The curriculum should provide experiences that build the knowledge and provide capabilities of thinking rationally, to understand the world through various disciplines, fosters aesthetic appreciation and sensitivity towards others to work and to participate in economic process. It provides the vision of capabilities and values that every individual must have. It also gives a socio-political and cultural vision for society. **In other words, curriculum is a complete plan for implementation of educational aims.**

Curriculum should respond to the new developments and the concern of the country.

The National Curriculum Framework-2005 provides following guidelines for curriculum development (Fig. 6.2).

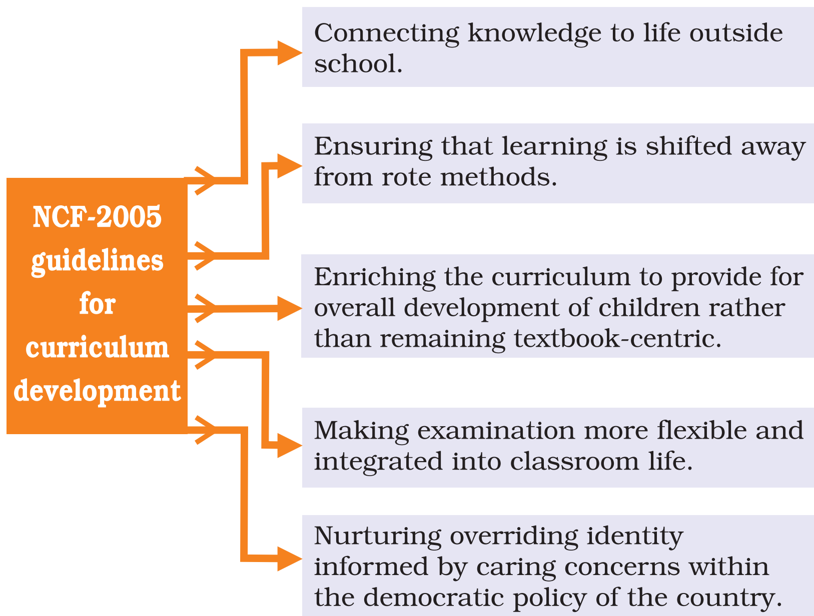
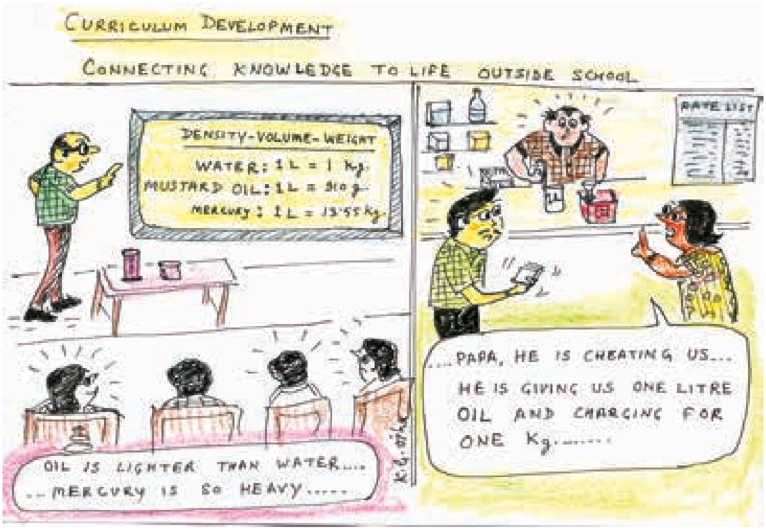


Fig. 6.2 *NCF-2005 guidelines for curriculum development*

The curriculum must have holistic approach to learning and development that is able to see interconnections and transcend divisions between physical, mental, social and emotional development of the learner and interactions with others. The curriculum should develop capacity to think, reason and make sense of self and the world, and to use language. The learner should become capable of doing things by oneself and with others.

National Curriculum Framework-2005 recommends that curriculum must enable children to find their voices, nurture their curiosity— to do things, to ask questions and to pursue investigations, sharing and integrating their experiences with school knowledge rather than their ability to reproduce textual knowledge.

6.3.3 School curriculum



As we have seen above curriculum is guided by curriculum framework and it pertains to learning experiences inside and outside the classroom, with enabling conditions needed for desired teaching-learning process. This leads to school curriculum, i.e. curriculum details.

It includes syllabus, textbooks, teaching-learning materials, recommended classroom practices and evaluation schemes.

The NCF in India sets the direction for teaching and learning in schools, but it is a framework rather than a detailed plan. **This means that while every school curriculum must be clearly aligned with the intent of the NCF, schools have considerable flexibility when determining the detail.** They can draw on a wide range of ideas, resources and models. Schools are required to base their curriculum on the recommendations of NCF.

A School located in Delhi uses NCERT syllabus and textbooks. Students use ‘hands-on’ and inquiry-based approach to science learning. Students of Classes IX and X have access to science laboratory. School library has many reference books on various disciplines of science. Teacher relates science to everyday experiences of students and uses contextual science learning material. Teacher takes the students to places of educational importance, whenever she feels it is required for learning. Students bring out a science magazine in which they contribute reflections on science learning, scientific innovations and science fiction. Students develop scientific models and participate in science exhibitions. School organises field visits, debates on science and social issues. School also organises quiz competition. Students work collaboratively on projects. Teacher makes school-based assessment of students on the basis of students' record of work and portfolio maintained by them.

ACTIVITY 6.2

Study the curriculum followed by the school you go for your internship programme and find whether it is in consonance with NCF-2005. Giving your constructive suggestions, present your report in the class.

6.3.4 Syllabus

It is a document that gives details of the content of subjects to be transacted and the skills, knowledge and the attitude which are to be deliberately fostered together with the stage-specific objectives. In India, NCERT develops exemplar syllabus for all stages of school education. States can adopt/adapt NCERT syllabus or can develop their own syllabus on the basis of NCF.

It will be interesting to know how the content to be transacted is chosen. To choose the content to be transacted, the requirements and challenges being faced by the country are considered. The challenge before our country is that of quality education. It demands that the education available to all children in different regions and sections of society be of comparable quality. Therefore, selection of knowledge to be included in each subject requires careful examination in terms of socio-economic and cultural conditions and educational goals. Quality in education includes a concern for quality of life and all its dimensions viz. concern for peace, protection of environment and positive attitude towards required social change, universal human rights and changes in pedagogy. **Education must provide the means and opportunities to enhance the child's creative expression and capacity for aesthetic appreciation.**

The criteria used for the development of syllabi by NCERT in 2005, evolved from NCF-2005 are listed below:

- Appropriateness of topics and themes for the relevant stages of children's development from a psychological point of view.
- Pervasive resonance of the values enshrined in the Constitution of India in the organisation of knowledge in all subjects.
- Continuity from one level to the next.
- Interdisciplinary and thematic linkages between topics listed for different school subjects which fall under discrete disciplinary areas.
- Linkages between school knowledge in different subjects and

children's everyday experiences and knowledge derived from them.

- Infusion of environment-related knowledge and concern in all subjects and at all levels, treating 'environment' as a holistic expression, covering nature, all forms of life, human values and socio-economic and cultural meanings of environment.
- Sensitivity to gender parity, peace, health and the children with special needs.
- Integration of work-related attitudes and values in every subject and at all levels.
- Need to nurture aesthetic sensibility and values by integrating the arts and India's heritage of crafts in every aspect of the curriculum.
- Linkage between school and college syllabi avoiding overlapping.
- Using the potential of educational technology which includes the new information technology in all subjects.
- Encouraging flexibility and creativity in all areas of knowledge and its construction by children.

6.4 FROM SUBJECT-CENTRED TO BEHAVIOURIST TO CONSTRUCTIVIST APPROACH TO CURRICULUM DEVELOPMENT

In order to understand the nature and direction of change in the curriculum development, let us try to understand various approaches to curriculum development that influence science curriculum.

Examine the following ways of writing a syllabus of a subject:

[A] Table 6.1 : A unit of science syllabus for Class VI, (NCERT , 1988)

Name of the Unit	Contents
Unit 4: **Measurement**	Observation of different types of measurement in daily life; need of various types of measurements; need of standard units; elementary ideas about basic units, MKS system, multiple and submultiple units; measurement of length; proper use of instruments; measuring diameter of spherical surfaces; measuring small thickness; estimation in daily life; measurement of area of regular and irregular surfaces; measurement of volume of solids and liquids; use of various devices in measuring length, area, volume; measurement of mass; need for accurate measurements in daily life; measurement of temperature, various types of thermometers; measurement of time.

Unit 13: **The Universe**	Numerous stars and planets in the universe; classification of heavenly bodies, galaxy, shapes and sizes of the heavenly bodies and idea of their distance from the earth; artificial satellites; various uses of artificial satellites; meteors and meteorites.

[B] Table 6.2 : Class VIII; A unit of science syllabus of a state in India (2007)

SI. No.	Lesson	Content	Skills	Expected Learning Outcome	No. of Period	Activity	Required Material
1.	**LIGHT**	• Dispersion of white light through a prism (qualitative) • Refractive index (as a ratio of speed of light in two media). • Application of lenses— magnifying glass, microscope, camera, telescope. • Human eye as an example of a natural lens.	• Define • Identify • Observe • Critical think-ing • Quest-ioning • Experi-ment	• Define light • Define dispersion • Observe and define the prism • Observe and describe dispersion of white light through a prism. • Conduct experiment to show dispersion • Define refractive index • List the uses of lens as in magnifying glass, camera microscope, telescope. • Realise that human eye is a natural lens.	1 2 2 2 1	Oral, written material	As required

[C] Table 6.3 : Class VII; A unit of science (NCERT, 2005)

Questions	Key Concepts	Suggested Resources	Suggested Activities/ Processes
Unit: 6 Natural Phenomena **Rain, thunder and lightning** What causes storms? What are the effects of storms? Why are roofs blown off ?	High speed winds and heavy rainfall have disastrous consequences for human and other life.	Experience; newspaper reports. Narratives/ stories.	Making wind speed and wind direction indicators. Activity to show 'lift' due to moving air. Discussion on effects of storms and possible safety measures.
Light Can we see a source of light through a bent tube?	Rectilinear propagation of light.	Rubber/ plastic tube /straw, any source of light.	Observation of the source of light through a straight tube, a bent tube.
How can we throw sunlight on a wall?	Reflection, certain surfaces reflect light.	Glass/metal sheet/metal foil, white paper.	Observing reflection of light on a wall or white paper screen.
What things give images that are magnified or diminished in size?	Real and virtual images.	Convex/ concave lenses and mirrors.	Open-ended activities allowing children to explore images made by different objects, and recording observations. Focused disussions on real and virtual images.
How can we make a coloured disc appear white?	White light is composed of many colours.	Newton's disc.	Making the disc and rotating it.

These three syllabi require different teaching-learning approaches and curricular materials. The role of teacher and learners also change in these classrooms. The nature of learning experiences and also the outcomes and evidences of science learning will be different in each case.

In the first approach **[A],** (Table 6.1) only subject knowledge (content) has been stated. This syllabus is based on 'subject-centred curriculum.' **The basic assumption in 'subject-centred curriculum' is that knowledge, which is objective and universal can be transmitted directly from those who have acquired the knowledge to those who have not.**

The teacher transmits subject knowledge to students through classroom instructions. Lecture is most commonly used method to communicate subject knowledge to students. Students generally memorise the subject content provided by the teacher/textbook. The teacher is considered to have all the right knowledge. Examinations test the content knowledge of students. While designing syllabus under subject-centred curriculum, experts select the content which is most important or worth teaching in schools. The debate still continues as to which knowledge is relevant and useful for students. The curriculum developers and teachers who view learning solely as acquisition of subject matter, may have difficulty in planning student's learning beyond recall or comprehension level. Mere recall of skills does not by itself directly change a student's understanding and analytical ability.

In the second approach **[B],** (Table 6.2) the syllabus or course of study has been stated in terms of both subject content and learner behaviour. It is 'Behaviourist Curriculum.' Behaviourist psychologists view learning as change in behaviour and learning objectives are defined in terms of behavioural change. Knowledge is the capability for action, identified as the 'successful performance of tasks.' For example, within the behavioural context student's ability to define dispersion of light falls as her knowledge. The only way to determine whether or not students 'know' or 'do not know,' something is to see how they behave in certain situations.

The behaviourist approaches to learning are based on following assumptions:

- Learning requires a change in the learner's behaviour which can only be gauged by what the learner does.
- Real competence comes only with extensive practice. The stimulus-response connection is strengthened with practice.
- The learning is strongly influenced by the feedback that tells the system when responses are correct and when they are wrong.
- Skilled performance requires that responses to stimulus be conditioned in such a way that a particular stimulus, automatically generates the specific response.

- The total learning of a student with respect to a complex task is summative accumulation of specific expected learning outcome associated with that task.
- Most complex skills are hierarchical in structure and can be broken down into simpler tasks.

ACTIVITY 6.3

Discuss the essential features of subject-centred curriculum and behaviourist curriculum. Do you think design of learning experiences is affected by approaches to curriculum development ? Explain with an example.

The competency-based curriculum, criterion referenced curriculum, and mastery learning and programmed learning are all based on behaviourist theories of learning. These approaches assume that large/complex tasks can be broken down into small/simpler tasks and these can be sequenced in order from simple to complex. The competency-based and programmed curriculum use these assumptions. In competency-based curriculum, terminal competencies are defined in behavioural terms. These are then sub delineated into sub competencies. Competency-based curriculum (minimum levels of learning) has been developed in India and some other countries.

One example of breaking down the complex task into simpler learning tasks is given below (Fig. 6.3).

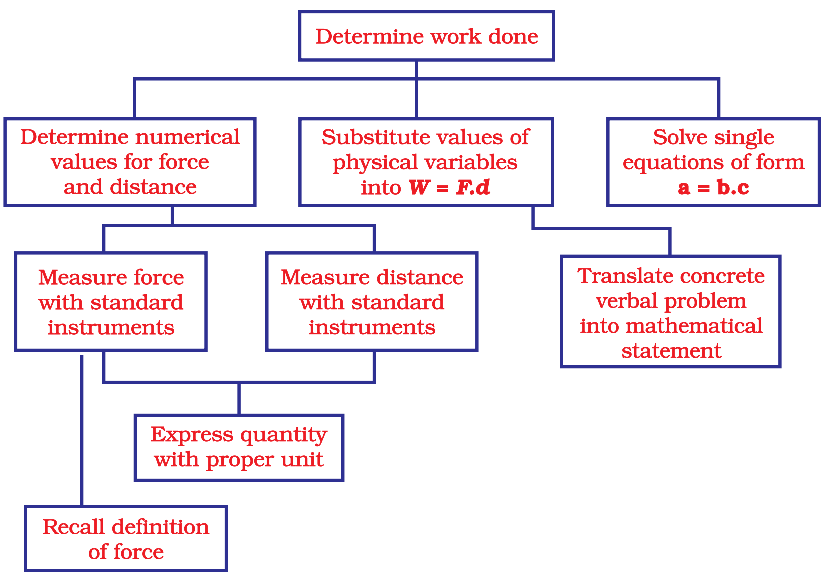


***Fig. 6.3** Breaking down the complex task into simpler learning tasks in competency-based curriculum*

ACTIVITY 6.4

Select a complex task from a textbook of science/physics/chemistry and break it into simple tasks.

ACTIVITY 6.5

Search on Internet and study one competency-based science curriculum. Share your findings with the class.

In behaviourist curriculum, teachers are instrumental to implement curriculum developed by curriculum developers. Teachers do not question 'ends or means of curriculum.' The behaviourist curriculum does not take into consideration the learner's experiences, context and cognitive predispositions. Learners are treated as passive receivers of knowledge and teacher as transmitter of knowledge. Chalk and talk is the common method of teaching. Learners memorise, recite or study their lessons silently without questioning. Childhood is viewed as preparation for adulthood within society. The education aims at developing such knowledge and skills which will be helpful for students to serve society in their adult life.

Critiques of subject-centred and behaviourist approaches say that these curricula do not help in achieving the aim of all-round development of the learner.

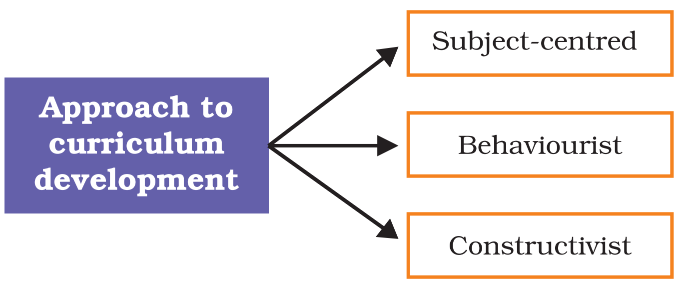


Fig. 6.4 *Approach to curriculum development*

The aim of learner-centred curriculum **[C],** (Table.6.3) is to stimulate and nurture growth of learners. The learner-centred educators stress that aim of education is growth and development of the learner and the orientation of the entire school should be towards the learner. Learners create meaning and thus, construct knowledge by engaging in stimulating experiences when they interact with their environment. Learners are innately curious and predisposed toward exploration.

The role of teacher is to provide learning environment and stimulating experiences to learners. From the learner-centred viewpoint, teachers must trust in the innate abilities of learners; in their capacity to direct their own exploration and learning. **Learner-centred curriculum views learning from a constructivist perspective. Learning takes place when learners engage with stimulating environment, get involved in inquiry and make meaning for themselves out of interactions with environment.** Learner-centred educators are interested in knowing, 'what is happening within' the learner between stimulus and response. The learner-centered educators are interested in parameters such as the state of learner's cognitive structures, her meaning-making abilities, and her creative spirit.

For 'constructivist curriculum' developers, it is the learning environment and experiences, that are of crucial importance and can be generated by taking into consideration the context of learner as well as teaching-learning environment. The curriculum must engage learners with stimulating experiences by arranging suitable learning environment.

'constructivist curriculum' is based on the following assumptions:

- Knowledge is actively constructed, invented, created, or discovered by learners. It is not passively received and stored by learners.
- Knowledge cannot be separated from the process of meaning-making or knowing or learner's experiences. It is based on learner's conceptual structures and prior experiences.
- Learners are constantly constructing and reconstructing their cognitive structures, both as a result of newly acquired knowledge and as a result of their reflection on previously acquired knowledge.
- Social interaction with peers and adults in a cultural context are extremely important in individual's construction of knowledge.
- Concept formation progresses from concrete to abstract slowly.
- Learners have different learning styles, and teaching–learning should accommodate these.
- The teacher in constructivist curriculum is provider of the learning environment and a facilitator of learning.

ACTIVITY 6.6

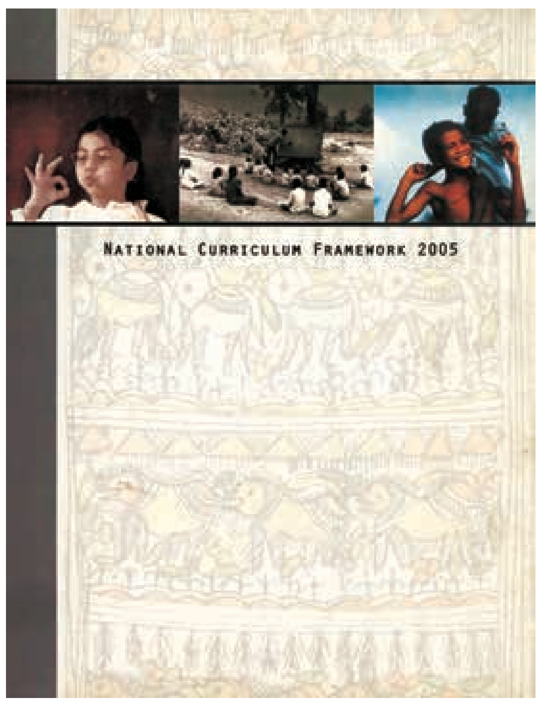
Discuss how curriculum approach at **C** (Table 6.3) is learner-centred. Share your views with the class.

Project 6.2
Analyse NCERT syllabi of Class VIII science based on National Curriculum Framework for School Education (NCFSE)-2000 and NCF- 2005. Discuss what type of curricular approaches have been used in these syllabi.

6.5 RECOMMENDATIONS OF NCFS ON SCIENCE CURRICULUM

The NCF of 1975 recommended 10+2 system of school education with general education of 10 years. The NCF of 1975 also recommends that general science should be a core compulsory subject up to Class X. The framework suggests activity-based integrated science up to Class X.

The 1988 National Curriculum for Elementary and Secondary Education (NCESE): A Framework recommends learner-centred science curriculum. It also recommends that general science should be a compulsory subject up to class X. The 1988 NCESE suggests that science education should aim at developing well-defined abilities in cognitive, affective and psychomotor domains such as spirit of inquiry, creativity, objectivity, the courage to question and aesthetic sensibility. At the primary stage during the first two years (Classes I and II), study of science should form an integral part of environmental studies. In Classes III, IV, V, it should be one of the two parts of environmental studies – one devoted to science and the other to social studies. At upper primary stage (Classes VI to VIII), learner is expected to consolidate and strengthen the abilities acquired at the primary stage. Science education at this stage should help the learner to develop skills of manipulation, handling simple science equipment and designing of simple experiments to seek explanations of natural phenomena. At the secondary stage (Classes IX and X), the aim of teaching science would be primarily directed towards problem solving and decision making through the learning of key concepts which cut across all disciplines of science.



The National Curriculum Framework for School Education (NCFSE)-2000 recommends teaching of science and technology at upper primary and secondary stage. At the primary stage, science should form an integral part of environment studies. NCFSE-2000 recommends teaching science and technology in Classes VI to X as a single discipline. It was felt that technology is increasingly influencing our lives and therefore, needs to be included in the science course. At the senior secondary stage, teaching-learning of science takes a disciplinary approach as physics, chemistry and biology.

The National Curriculum Framework-2005 recommends hands-on, inquiry-based science curriculum. NCF-2005 also addresses the issues of curriculum load, rote memorisation and rigid examination system. NCF-2005 suggests flexible examination system and time schedule, reducing curriculum load and integration of theory and practical work in teaching-learning of science. NCF-2005 recognises learner as constructor of knowledge and suggests that learners be provided with learning-experiences which enable them to inquire, solve problems and develop their own concepts.

At the primary stage, the child should be engaged in joyfully exploring the world around and harmonising with it. The main objectives at this stage are to arouse curiosity about the world (natural environment, artifacts and people) and to engage the child in exploratory and hands-on activities.

At the upper primary stage science education should provide a gradual transition from environmental studies of the primary stage to elements of science and technology. Science content at the upper primary stage should not be governed by disciplinary approach. At this stage the child should be engaged in learning the principles of science through familiar experiences, working with hands to simple technological models.

At the secondary stage, students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological models than at the upper primary stage.

At the higher secondary stage, science should be introduced as a separate discipline, with emphasis on experiments/technology and problem solving.

ACTIVITY 6.7

Read Chapter 3 of NCF-2005. For this you may visit www.ncert.nic.in. Give a presentation in the class regarding curriculum of science at various stages of learning.

6.6 TRENDS OF NCERT SYLLABI

The analysis of syllabi prepared by NCERT in 1988, 2000 and 2005 reveals that there is a shift in approach to syllabus development. There is a shift from information loaded content to 'activity-based' integrated science syllabus to 'learner-centred' syllabus.

The 1988 syllabus has been spirally developed, detailing the competencies, concepts and activities appropriate for the stage of schooling and graded in terms of difficulty level and depth. The real-life issues related to problems of *Food and Nutrition, Health, Population, Agriculture and Environmental Protection,* form the essential components of science learning.

Now, study one unit of syllabus of Class VI developed by NCERT on the basis of 1988, 2000 and 2005 National Curriculum Frameworks, respectively as given below in Table 6.4, Table 6.5 and Table 6.6**.**

Table 6.4 A unit of science syllabus for Class VI developed in 1988

Name of the Unit	Contents
Unit 6: **Motion, Force and Machines**	Moving and stationary objects; different types of motion—linear, random, rotatory, circular, periodic, oscillatory; speed, force; change in speed, direction and shape by applying force; various types of forces—magnetic force, electrostatic force, frictional force; advantages and disadvantages of friction; minimising and increasing friction; different kinds of simple machine–lever, inclined plane, pulley and wheel; complex machines — a combination of simple machines; maintenance and care of machines.

Table 6.5 A unit of science syllabus for Class VI developed in 2000

Name of the Unit	Contents
Unit 9: **Force and Motion**	• Force; effect of force (change in shape, size, motion); unit of force; pressure and pressure in fluid. • Idea of motion: types of motion (rectilinear, rotational, oscillatory, periodic and non-periodic-elementary idea)· • Uniform and non-uniform motion along a straight line; idea of velocity. • Speed; unit of speed.

Table 6.6 A unit of science syllabus for Class VI developed in 2005

Questions	Key Concepts	Suggested Resources	Suggested Activities/ Processes
Unit 4: **Moving Things, People and Ideas**			**(Period - 12)**
How did people travel from one place to another in earlier times? How did they know how far they had travelled? How do we know that something is moving? How do we know how far it has moved?	Need to measure distance (length); Measurement of length; Motion as change in position with time.	Everyday experience; equipment (scale, etc.) to measure length. Stories for developing contexts for measuring distances.	Measuring lengths and distances. Observation of different types of moving objects on land, in air, water and space. Identification and discrimination of various types of motion. Demonstrating objects having more than one type of movement (screw motion, bicycle wheel, fan, top, etc.); observing the periodic motion in hands of a clock/watch, sun, moon, earth.

We observe that 1988 science syllabus for Class VI is presented as a list of topics. The approach was to rapidly acquaint children with the content of science without giving due importance to the process of science. Many topics like *Force, Friction, Galaxy,* etc. have been included in Class VI syllabus. These topics can come later in Class VIII or IX as these require understanding of abstract concepts also. In such syllabi, the intended depth is not clear. The list of topics to be transacted at times, is over specified or underspecified. Syllabus is under specified because list of topics fails to define the intended breadth and depth of the content. It is over specified in that it attempts to enumerate items of content knowledge which could easily have been left open.

The syllabus of 2000 was also loaded with information as the syllabus of 1988. The intended depth and breadth of the content coverage was not clear. The upper primary and secondary science curriculum uses science, technology and society approach. The focus is to acquaint children with the content of science and its application in technology. A thematic approach was adopted to organise the syllabus. The themes selected were *Universe, Our Environment, Matter, Measurement, the Living World, Energy, Nutrition and Health and Agriculture.* Most of these themes continue throughout the upper primary stage and continue even up to the secondary stage. An attempt was made to arrange the concepts in hierarchical order from Classes VI to X. These themes have been further divided into chapters that contain suitable content and also indicate extent of coverage.

NCF-2005 recommends that emphasis should be laid on the active participation of the learner in the construction of their knowledge. While developing science curriculum in 2005, it was decided not to combine technology with science. The information load in syllabus was reduced and only age appropriate concepts were included. The syllabus was prepared in the light of NCF-2005 and recommendations of the report '*Learning without Burden*' were also considered. A thematic approach was adopted to organise the content and the syllabus was framed along cross disciplinary line. The themes included in the syllabus were *Food, Materials, The World of the Living, How Things Work, Moving Things, People and Ideas, Natural Phenomenon and Natural Resources.* These themes run from upper primary to the secondary stage and there is consolidation of themes at the secondary stage. The 2005 syllabus has been presented in four columns titled as questions, key concepts, suggested resource and suggested activities.

The syallabus starts with questions. These are key questions which are meant to provide points of entry for the child to start the process of thinking. The activity column lists experiment as well as other classroom processes in which children may be actively engaged, including discussion. Although the items are suggestive in nature, they are meant to give an idea of the unfolding of the content. If you read activity column together with the questions and key concepts; they give the intended depth and breadth of the content coverage.

The syllabus provides clues for teaching-learning strategies and choosing content for textbook writing. It also has space for learners to perform activities/experiment. The local context also finds place in this syllabus. NCF-2005 recommends plurality of textbooks and relating science to everyday experiences of students.

For teaching-learning of science, NCF-2005 recommends a pedagogy that is hands-on and inquiry based. While this is widely accepted at the idea level, practice in India still tends to be dominated by chalk and talk methods. To make any progress in the desired direction engaging learners in inquiry and involving them actively in teaching-learning process is important. In 'hands-on' way of learning science, we start with things that are directly related to the learner's experiences and can be taken as concrete examples. In subject-centred approach, concepts are arranged in a hierarchical order, but in learner-centred approach, concrete situations come first followed by abstract concepts.

An example is the concept of electric current. If we think that the concept is abstract and needs the knowledge of movement of charge, then it should be treated at later stage only when the child is comfortable with the concept of charge. Charge is an abstract concept and is understood at a higher stage. However, we see that children can easily make simple electrical circuits and understand the concept of current. Therefore, concepts of *Electricity and Circuits*, *Electric Current and Its Effects* have been included at upper primary stage.

Project 6.3
With reference to science/physics/chemistry, analyse trends in syllabus development in your state over the past few years.

6.7 MOVING FROM TEXTBOOK TO TEACHING-LEARNING MATERIALS

The textbook as a part of teaching-learning materials, is a tool to engage the learner. The teacher in classroom practices can use a variety of activities, concrete learning materials along with textbooks. When we come to decisions regarding approaches of teaching-learning, learning materials and concrete examples to be used, we have to consider learning needs of the learners. These concrete decisions can be made only for specific classrooms and children as the actual learning happens only in the child's mind and depends totally on what has been learnt earlier. Therefore, the reinterpretation of the content, approaches, and materials are completely within the sphere of practical decisions to be made by the teacher.

A textbook may not necessarily cover the entire syllabus of one class/stage and it may not necessarily be for the whole year. Any good textbook should lead the child to interact with the environment, peers and other people rather than be self-contained. **A textbook should function as a guide to construct understanding through active engagement with text, ideas, things, environment, and people rather than transferring knowledge as a finished product.** The recent attempt by NCERT to prepare syllabus based on NCF-2005 aims at making the syllabus an enabling document for the creation of textbooks that are interesting and challenging without being loaded with factual information. Overall, science has to be presented as a growing body of knowledge rather than a finished product. In the light of this argument, what is needed is not a single textbook, but a package of learning materials that could be used to engage the learner in active learning and inquiry.

ACTIVITY 6.8

Analyse any textbook of science at upper primary in the light of above discussion and prepare a report.

ACTIVITY 6.9

Find what teaching-learning materials have been developed by your state for different stages of learning. Analyse them in the light of NCF-2005.

6.8 TEACHER AS CURRICULUM DEVELOPER

The foregoing discussion gives an understanding of the process of curriculum development. The next question you may like to ask is, "What is the role of teacher in this exercise of curriculum development?" In India, curriculum is developed either at the centre or state level and teachers are viewed as implementers of this externally developed curriculum. During pre-service teacher preparation programmes, curriculum and teaching are studied independently and are treated as separate entities. The focus is on 'teaching methods/curriculum transaction'. Student-teachers are not exposed to curriculum development processes and are not given opportunities to analyse and reflect upon the existing curriculum practices. During in-service training programmes also, focus is on 'teaching strategies' and curriculum development is not included in the training course. Teachers' role is viewed as transacting the prescribed syllabus and textbooks and 'covering' the entire syllabus in time. Since teachers are not given critical understanding of curriculum development during pre-service and in-service programmes, they fail to draw connectivity between curriculum and teaching-learning and continue to teach using same traditional lecture-cum-demonstration method. As you have learnt in this chapter, **Curriculum is conceptualised as a planned course of action for intended learning while teaching-learning deals with how the proposed curriculum should be transacted.** Curriculum is seen as an end and teaching–learning as a means of achieving the end. Teachers are expected to transact the prescribed syllabus in the classrooms implementing prescribed method of teaching or strategies of curriculum transaction. Such practices encourage rote learning and discourage creativity and innovative practices.

However, now teacher-educators and curriculum planners have started realising the importance of having teachers in curriculum committees. Most teacher-educators and teachers now agree that teachers must be given understanding of curriculum development. Teachers must critically review curriculum, syllabus and textbooks. Inclusion of teachers on curriculum committees helps in improving the curriculum. Teachers bring to curriculum committees their reflections on classroom practices. Teachers' practical knowledge of classroom teaching learning helps in assessing the workability of the curriculum and curricular material. When curriculum is developed based on teachers' successful classroom practices, it is more relevant to the needs of children in the school. Teachers can field test curriculum in diverse classrooms, and can bring students' problems and schools' needs to the surface. Curriculum can support teachers honestly only if it has been developed through intense partnership with teachers.

Teachers' participation in curriculum development is also a matter of taking position between centralised and decentralised curriculum. More teachers can participate in the process of curriculum development, if curriculum is developed at the district or school level. When curriculum is developed at the state or centre level, only a few teachers can be included in the curriculum committees.

ACTIVITY 6.10

What is your opinion about involvement of practising teachers in curriculum development? What should be their roles in curriculum development? Discuss in the class.

6.9 SUMMARY

We have discussed above, how a sound understanding of curriculum of physical science helps a teacher in teaching-learning process. A National Curriculum Framework provides guidelines within which teachers and schools of a country can choose and plan experiences that they think children should gain.

We have also seen above that curriculum is a plan of facilitating learning for a child. Teacher can start this plan from where the child is enumerating all the aspects and dimensions of learning that are necessary, giving reasons why such and such learning is considered necessary, and what educational aims it would serve. In this plan, the teacher also considers stage specific objectives of learning science, what content to transact and how to organise it. **A good understanding of curriculum also facilitates the teacher to get insight into general principles of teaching-learning approaches and evaluation, criteria for a good teaching-learning materials, providing equal access to all children in the activities, experiments and all classroom transactions in an equitable way.**

It is important to recognise that education is a process and experience is a significant part of this process. Unless the learner can locate her standpoint in relation to the contexts represented in the classroom experiences and relate the knowledge with her everyday life experiences, knowledge is reduced to the level of mere information. Therefore, all curricular experiences have to be designed to ensure that learners with varied needs enjoy and relate to teaching-learning processes. Teacher should make science curriculum accessible to all learners by bringing flexibility at suitable points of interaction.

EXERCISE

6.1 Compare the perspective of science curriculum in the NCFs from 1975 to 2005.

6.2 Explain the following terms:

(i)	Curriculum framework	(ii)	Curriculum core
(iii)	Curriculum	(iv)	School curriculum

6.3 What guidelines have been given in NCF-2005 for the development of science curriculum and syllabus? Discuss in detail.

6.4 Which of the following do you think is more appropriate level for the development of science curriculum?

(i)	Center	(iii)	District
(ii)	State	(iv)	School

Give reasons for your answer.

6.5 In the light of NCF-2005, discuss how learning of physical science can be shifted from rote memorisation to the construction of knowledge.

6.6 What are the guidelines given in NCF-2005 to connect the knowledge with the world outside school?

6.7 What were the recommendations of 1988 curriculum framework about the role of a teacher? Has the role of the teacher changed since then? Discuss what changes do you note?

6.8 Comment on the phrase, 'the curriculum must have holistic approach to learning.'

6.9 Can school curriculum make difference in learning environment in two different schools? Explain your answer giving examples.

6.10 What parameters would you consider in analysing syllabi of science/ physics/chemistry? Critically compare analysis of the syllabus of your state with any other state or with that of NCERT.

6.11 Disscuss the criteria used for development of stage specific syllabus of physical science on the basis of NCF-2005.

6.12 What are the differences in subject-centred, behaviourist and constructivist approach to curriculum development? What is the role of teacher in these approaches in teaching-learning of science?

6.13 Explain the characteristic features of learner-centred curriculum of physical science with examples.

6.14 'A package of learning materials and not a single textbook could be used to engage the learner in active learning.' Comment.

6.15 Discuss the role of a teacher as curriculum developer.

6.16 How does a sound understanding of curriculum development help a science teacher in her teaching-learning process? Explain.

6.17 Examine critically the part of the Class VII syllabus of a state which is given below. Explain what approach of curriculum development has been followed in developing the syllabus. Would you like to modify it? Justify your answer.

Table 6.7 A unit of Class VII syllabus of a state

Lesson	**Contents**	**Skills**	**Expected Learning Outcomes**	**No. of Periods**	**Activity**	**Required materials**
Work and energy	• Examples of work done from daily life. • Simple machines- Levers, inclined planes, screw, wheel, axle and	Identifying, Observing, Classifying, Questio-ning, Critical thinking.	• Recall the definition of work and energy. • List the examples of work done from daily life. • Describe the	1 1 2	Oral, Written Material	• Charts showing examples of work done from daily life. • Charts showing relation between work and energy.

Lesson	Contents	Skills	Expected Learning Outcomes	No. of Periods	Activity	Required materials
	pulley. • Work and Energy : Kinetic and potential energy, chemical, heat, light sound, magnetic and electrical energy. Transfor – mation of energy from one form to another. • Techno-logical applicat-ions of levers; steel yard, platform balance.		relation between work and energy. • Realise that we need energy in the form of food to work. • List the forms of energy. • Define kinetic and potential energy. • Define chemical energy. • Define heat and light energy. • Define sound energy. • Define magnetic energy. • Define electrical energy. • Describe the trans-formation of energy from one form to	 1 1 1 1 1 1 1 1 2		• Real objects (screw, pulley, wheel). • Charts showing transfor-mation of energy from one form to another • Charts showing descrip-tion of levers; steel yard, platform balance.

Lesson	Contents	Skills	Expected Learning Outcomes	No. of Periods	Activity	Required materials
			another with experi-ments. ● Describe the techn-ological applicat-ion of levers. ● Describe steel yards. ● Describe platform balance.	 2 1 1		

Chapter 7

Pedagogical Shift in Physical Science

7.1 INTRODUCTION

In the previous chapter we have discussed how science curriculum has changed over time and the job of a science teacher has now become more challenging. Science is an enterprise that has been changing continuously over the years. There is a shift from understanding science as mere collection of facts and principles to the constructivist and inquiry-oriented learning experiences taking learner at the centre stage. The role of classroom discussion in promoting critical, creative and reflective thinking of learners and thus collaborative participation in the classroom have been identified as being centre to the construction of their knowledge. Moreover in the present age of globalisation, information and communication technology has directly or indirectly affected our education system. Learners need to develop a knowledge base to assimilate knowledge from print and electronic media to make sense of it.

Pedagogy of science deals with strategies of teaching-learning, organising classroom experiences, knowledge about preconception of learners and transacting the concepts to diverse groups of learners relating with their preconception, so that they can assimilate and accommodate new information to make meaning of it. We need to recognise that with the creation of new knowledge all over the world, sociocultural and economic conditions of our society change, new opportunities of work arise and aspiration of people grow. This dynamism of society must be reflected in the pedagogy of science. **Today's pedagogy gives value to the voice of learners and their questions, their abilities of making argumentation and justification, synthesising and analysing knowledge and their involvement in the process of inquiring science in a collaborative set-up rather than their ability of rote memorisation.** Consequent to the implementation of NCF-2005, a shift in pedagogy is taking place in our country. There is also a shift in our understanding of process of learning and about learners in the classrooms. The nature and origin of knowledge is going through continuous debates. It has been repeatedly emphasised that these developments should translate themselves in ways and forms making them accessible to learners. In the present chapter, we shall pay our attention to new developments and insights on the issues related with the pedagogy of physical science.

Foundation of modern Indian education was laid down by the thinkers like Aurobindo Ghosh, Rabindra Nath Tagore, Mahatma Gandhi, Maulana Abul Kalam Azad, Sarvepalli Radha Krishnan. Almost all the pedagogies related with content knowledge deal with learning and knowledge. Thus, to make any alternate pedagogy successful and meaningful in a given context, there is a need to understand the epistemic and epistemological dimensions of learning. We know that without understanding learning (as a process as well as product) properly we cannot understand the pedagogy that we want to implement in the classroom for teaching and learning of physical science. Pedagogy includes both teaching as well as learning process of learners. Hence, there is a need to understand the nature of learning and nature of teaching with reference to physical science. Teaching–learning is a collaborative process in which sometimes teacher may work as a student and sometimes student may work as a teacher and they share knowledge with each other.

7.2 PEDAGOGICAL SHIFT FROM SCIENCE AS FIXED BODY OF KNOWLEDGE TO THE PROCESS OF CONSTRUCTING KNOWLEDGE

Earlier, nature of knowledge in general and nature of knowing in particular was considered as a fixed entity. However, in the contemporary understanding of nature of knowledge and nature of knowing, these are dynamic entities. **Thus, the pedagogy which we use to construct knowledge through diverse learning strategies includes previous experiences of the learner, their sociocultural and economic background along with the content knowledge rather than overwhelming emphasis on the psychological characteristics to the individual learner.**

Till recently, the main purpose of studying science was perceived as 'acquiring' scientific knowledge. Now, there is a shift in perception regarding this purpose. This shift is tilted towards 'construction' of scientific knowledge, not the passive acquisition of factual knowledge. Construction of scientific knowledge concerns knowledge of 'how to do things' scientifically (here, doing is not confined to manual activity only, it could be mental activity also) and, perhaps, that is why scientific knowledge is always the result of a constructive activity. Therefore, the fundamental difference between the acquisition and the construction of scientific knowledge is passive receipt of the knowledge, and active involvement and critical examination based on critical thinking on the part of the learners.

Shift in pedagogy of science from a fixed body of knowledge to the process of constructing knowledge has many dimensions. It includes a shift in our understanding of nature of science; nature of knowledge; learners, learning and teachers; assessment; science curriculum; scientific method and scientific inquiry; importance of critical pedagogy; approaches to planning; various aspects of inclusive education; etc. In order to understand pedagogical shift in physical science, it is important to have a brief overview of all these aspects related with teaching–learning in science.

7.2.1 Pedagogical shift: Nature of science

From Chapter-1, **we have come to understand that unlike earlier beliefs and understanding no single method exists that can be termed as method of science, rather, there are many features common to scientific enterprise that can be seen as scientific approach which may have explanations supported by empirical evidences and testing of result in terms of its efficacy in nature.** We also come to understand that the knowledge in science is subject to change i.e. it is tentative in nature. This tentative nature of scientific knowledge interestingly does not make it unreliable. We now realise that there is always an element of subjectivity in the development of scientific knowledge, even if we consider that science always strives for objectivity. Sociocultural factors also have impact on nature of science. Role of creativity, observation, inference, etc. have been understood to be important in the development of science. In simple terms, we can say that scientists collect relevant data and use evidences to explain ideas under consideration. They use their own perspective to guide themselves about problems. Scientists can change their ideas on the basis of contemporary development in their fields and create new ideas. **In order to understand science, we must know the manner in which knowledge is constructed over time as well as the method used to validate that knowledge and the place of science in society.**

7.2.2 Pedagogical shift: Knowledge

Science is an enterprise that has evolved over many thousands of years and continues to evolve. We have discussed that our understanding of knowledge has shifted from a 'static entity' to a 'dynamic entity.' Considering knowledge as a static entity to be transferred to learner's mind, makes her passive receiver of knowledge without engaging in thinking and questioning. We understand that knowledge is actively constructed by learner and cannot be passively received. So learning is something done by the learners and not something that can be imposed on them. Knowledge can be conceived as experiences organised through language into structures of concepts, thus creating meaning which in turn helps learners to understand the world they live in. Scientific knowledge can be represented in the form of conceptual structures and they can model these structures to describe them. Fig. 7.1 Shows how growth of scientific knowledge takes place.

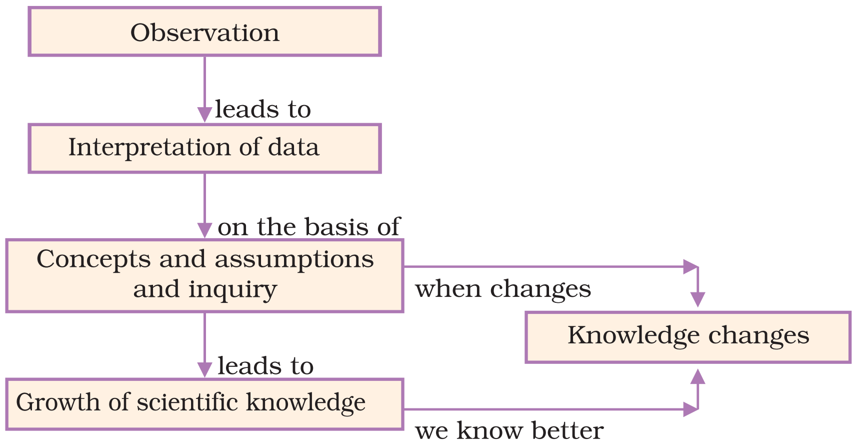


Fig. 7.1 *Growth of scientific knowledge*

Thus, scientific knowledge is always subject to change and its modification is not an end product in scientific inquiry. Teaching–learning of science should go beyond presenting the facts and principles and result of investigations. It should also show the process of achieving them and how do we arrive at understanding.

Although knowledge is something personal and individual, the learners construct their knowledge through their interactions. These interactions involve interactions with the physical world, collaboratively in sociocultural settings and linguistics environments. Learners should be facilitated to make observations, collect and interpret data, use the acquired information in critical way to construct their knowledge.

ACTIVITY 7.1

Taking example of any concept in physics/chemistry, discuss how growth of scientific knowledge has taken place over years.

7.2.3 Pedagogical shift: Learners, learning and teachers

We have developed a more integrated understanding of learners and process of learning and we see them in inseparable form. Learners come to the learning situations in physical science with their existing ideas about phenomena, not just around them but across the real physical realm within their reach.

Some of these ideas are relatively temporary and unstable; many other are deep-rooted, well developed and difficult to be changed. Although these ideas are individual in nature, there are many commonalities. Some of these ideas are socially and culturally embedded, they are supported by language and metaphors and work as tools to understand many phenomena. These ideas many a times are in contrast and odds with the scientifically accepted ideas, and are hard to change. **Thus, for an effective pedagogical design, a teacher has to take care of the existing ideas of the learners and the difference in nature of their ideas with the scientific explanation of those ideas.** She should develop the habit of listening to learners, giving value to their ideas and motivating them to bring their own ideas about their observation and interpretation of phenomena in their own context. Not only this, they should be encouraged to critically evaluate and raise questions on established scientific understanding. This way learners' role in negotiating and mediating learning can be emphasised as we have discussed in Chapter-5. We need to develop in learners, the ability to discover the alternate meaning in the process of construction of their knowledge.

In Chapter-4, we have studied various aspects related to writing learning objectives. In the historical context, the classical work done by Bloom has guided the process of planning lessons for the child in the classroom for quite a long time. In 2001, that was modified further by Anderson and Krathwohl. There have been substantial changes in the way we look at the process of learning from behaviourism to cognitivism to constructivism. These changes have been placed through the research carried out in the field of educational practices. Focusing on learners' conceptions in science, it is worthwhile to mention the debate concerning the nature and status of these conceptions. The conceptual change in ideas has got support from researchers. These researchers also raised questions about the nature of students' learning and nature of knowledge, in particular scientific knowledge compared to the students' intuitive conceptions. The individual conceptual view of learning developed from the child development theories of Piaget were known as personal constructivist's view of learning. Constructivism is however, being considered as a very broad approach. Within the constructivists' perspective also there had been a shift from personal to social constructivist perspective. Vygotsky's ideas have provided a framework for the centrality of community in knowledge production. Effective teaching–learning in these recent frameworks involving performance of activities and the indulgence of learners in conversation not only challenge the model of discourse of science and perspectives to interpret evidences, but also provide for a richer way of looking at the world. Another perspective embedded in socio-cultural view realises that the context in which explanations are generated offer the ideas that can be used. Generally known as *situated cognition*, this tells us that children many times compartmentalise what they learn in classrooms as school knowledge that needs to be repeated and recalled during examination. They do not find them relevant to general situations. We can see children around us who seem to be incompetent at mathematics in a school, operating extraordinarily in sophisticated numerical procedures when operating as seller of some goods. Thus, we find that the social constructivists and situated cognition perspectives put the teacher and community back in the picture of facilitating the child in constructing knowledge in science.

Even though from long time, there was a need for child-centered education, it is through NCF-2005, a child-centred pedagogy is advocated. Child centered pedagogy means giving primacy to children's experiences, their voices, and their active participation. **The learning of science must help them nurture their curiosity, rather than their ability to reproduce textual knowledge. This shift is necessary to make learning atmosphere conducive and learning more meaningful.** The abilities of learners and their diversity have to be recognised. So teacher's role must be to facilitate learners' ability to construct their knowledge. The learners are seen as active participants rather than a passive recipient in the process of learning. Let us see the following example:

Students of Class XI had to draw cooling curve taking hot water in beakers. Azhar, the teacher, facilitated them to perform the experiment and encouraged them to discuss about possible errors in the observation. When students constructed their knowledge about loss of heat through conduction, convection and radiation, Azhar helped them to understand the use of a *calorimeter.* The class was working in four groups. Three groups carried out the experiment using *calorimeter.* However, one group wanted to use a thermos flask to perform the experiment arguing, it would prevent loss of heat to the surrounding in a better way. Teacher gave them this liberty. Students concluded on their own that when different parts of an isolated system are at different temperature, a quantity of heat transfers from the part of higher temperature to lower temperature.

Now, learners' capabilities and potentialities are seen not as fixed, but dynamic and capable of development through self experiences. Therefore, they should be encouraged to reflect and test their ideas with peers and teachers. To achieve this, multiple learning contexts are recommended which draws illustrations from life situations. **A constructivist teacher must be therefore trained as a critical analyser of syllabi, textbooks and a reflective practitioner of her own teaching-learning practices.**

ACTIVITY 7.2

Discussing with your classmates and teacher-educator, design various parameters of a learner-centred classroom.

There is a major shift in the teacher's role from where she assumes a position of centre stage as a source of knowledge as to being a facilitator of transforming knowledge and as a supporter in enhancing learning through multiple exposures, encouraging the learners to continuously achieve their educational goals. She is no longer considered as custodian and manager of all teaching-learning processes. **Learners have now taken the central stage. Their viewpoints are sought and valued. Learners get motivated to learn when they discover their own ideas, asking their own questions and trying to find out answers for themselves.** Teacher offers the learners, choices and options and invites their ideas in teaching-learning situations rather than telling them what to do. The shift is on accepting multiple views rather than accepting one correct answer from all students. Negotiation and mediation by learners, plays a prominent role in learning that takes place in a social set-up. Learners enter into dialogue and argumentation in learning science to construct their knowledge.

7.2.4 Pedagogical shift: Assessment

The purpose of assessment is necessarily to improve the teaching-learning process and to be able to review the objectives that have been identified for different stages of learning. Needless to say, this does not mean that test and examinations will have to be conducted frequently. On the contrary, routine activities and exercises can be employed effectively to assess learning. In addition to learner's achievement in various subject areas that can be tested easily, assessment needs to encompass attitudes to learning, interest and the ability to learn independently.

Furthermore, to test all the learners through a written test of the same type in all subjects is unfair to those whose verbal proficiency is superior to their writing skills or those who work more slowly but with deeper insight. NCF-2005 recommends a shift in modes of assessment by making it more flexible. It emphasises various modes of assessment including all meaningful aspects of performance, e.g. activities, experiments, journals, illustrations, oral presentations, peer evaluation, self evaluation, group work assessment, models, portfolios, and other artifacts of learning. We shall discuss in detail about assessment for physical science in Chapter 11.

Learners may be involved in selecting learning indicators and evaluation criteria to provide a sense of ownership in learning. **There is shift in emphasis from testing rote memorisation to understanding and application to the knowledge and from examination-centered classroom processes to learning-centred classroom processes.** The focus of question should move from mere plug-in type problems to genuine application type problems and questions demanding organisation of thoughts into arguments to demonstrate interpretative skills and critical thinking.

7.2.5 Pedagogical shift: Science curriculum and scientific inquiry

Most of the science curricula of 1960s and 1970s suggested that by *doing science*, students will automatically come to understand the nature of science and scientific inquiry. This approach was adopted and hands-on activities and process skills instruction were included in the science curricula. In that approach, it was assumed that scientific inquiry is related with the development of process skills such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analysing data. By assuming that the so-called fixed set and sequence of steps (generally known as scientific method) is a representation of multiplicity in terms of the approaches of inquiry followed by scientists, one important understanding about scientific inquiry was missing. It was about engaging learners in scientific investigations to find answers of self indentified questions.

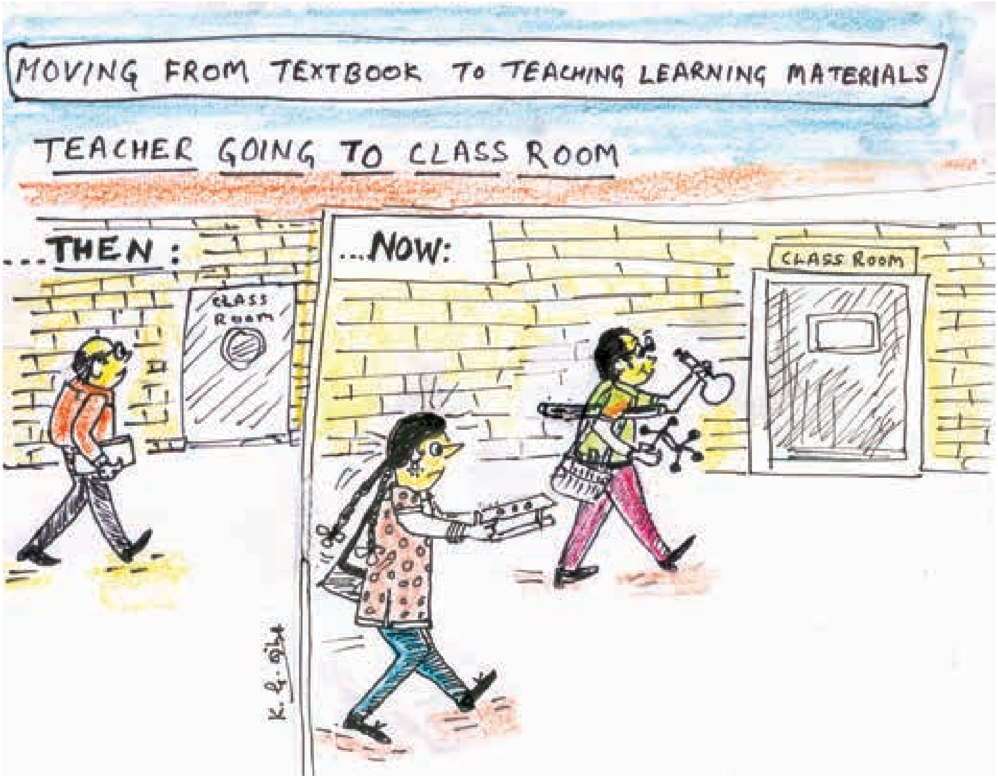
In order to deal with this gap in the implicit approach to scientific inquiry, historical approach was suggested.

Historical approach assumed that incorporating history of science will ensure that students understand nature of science and scientific inquiry. Researchers have shown that both these approaches (implicit and historical) have failed in developing the understanding of nature of science and scientific inquiry among learners. There is another approach which suggests that in order to improve students' views of scientific endeavour, learning of scientific inquiry should be well-planned and cannot be expected as a side effect of various approaches of teaching-learning science. This is sometimes referred as explicit, reflective approach. It is important to mention here that the contemporary view of scientific inquiry suggests that the questions which are asked or are to be answered guide the scientific inquiry in terms of methods that are used by our scientists. Thus, the scientific inquiry varies widely within scientific disciplines and also across various disciplines. Inquiry as a teaching-learning approach will thus mean placing learners in situations that are very similar to something that scientists experience during the daily journey of scientific endeavour. **Various approaches of involving learners in inquiry can be engaging learners in asking and raising questions, and encouraging them in investigations and processes of science.** In terms of science curricula, we need to emphasise the importance of merging classroom experiences of a learner in science with the experiential construction of scientific knowledge by the learner outside the classroom boundaries. **Instead of strict adherence to curriculum, pursuit of learners' questions needs to be emphasised.**

Learners' existing concepts should be explored rather than seeking correct answers to validate their learning. The present curriculum framework is trying to accept, acknowledge and incorporate those shifts in pedagogical processes. The pedagogical shifts recommended in NCF-2005 are indicated in Table 7.1.

Table 7.1 Major shifts in pedagogy

From	To
• Teacher centered, fixed designs	• Learner centered, flexible process
• Teacher's direction and decisions	• Learner's autonomy
• Teacher's guidance and monitoring of learning	• Teacher's facilitation, support and encouragement for learning
• Passive reception in learning	• Active participation in learning
• Learning within the four walls of the classrooms	• Learning in the wider social context
• Knowledge as 'given' and 'fixed'	• Knowledge as it evolves and is created
• Disciplinary focus	• Multidisciplinary, educational focus
• Linear exposure	• Multiple and divergent exposure
• Assessment—short, few	• Assessment—multifarious, continuous



7.2.6 Pedagogical shift: scientific method to science as inquiry

According to Nobel Laureate in Physics (1993) Russell A. Hulse, scientific method is an approach to seek knowledge in which scientists weave their ways back and forth as they inquire. They wonder, question, gather data and analyse. The question that strikes mind of a scientist is treated as problem. She/he guesses and thinks about several possible answers and solutions to the problem. She/he benefits by knowing what others have already discovered and use it as a framework on which she/he builds her/his knowledge. Thus, **scientists suggest answers to the question being investigated in not just very personal way, but in participation with what is known as scientific community.** This is how a hypothesis is formulated. Hypothesis formation is a creative process embedded in a holistic framework. In her/his work, a scientist may have to depend upon the findings of others and ultimately a problem may be solved by the accumulated efforts of several scientists.

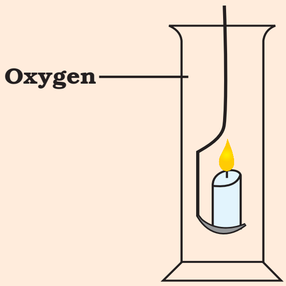
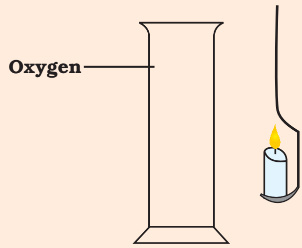
Once the hypothesis is tested, a conclusion results. This may result in a new discovery. Thus, science is both the study of knowledge and the process of acquiring and refining knowledge. Learners of science should be exposed to scientific method which helps them to develop the power of reasoning, critical thinking, creativity, collaborative learning and application of scientific knowledge. However, at the same time we should explicitly classify that the scientific method is not the only method of inquiry in science. In the chapter on *Nature of Science,* we have already discussed what a scientist does in the process of generating scientific knowledge. We have also discussed about various steps of scientific methods. **Scientific methods are ways of thinking and inquiring that allows investigating and explaining natural phenomenon and solving problems scientifically. A scientific method does not prescribe series of steps to be followed rigidly, rather it is a series of dynamic and flexible steps by which reliable evidence can be gathered.** The typical steps to be followed depends on the specific problem being solved. Following are some illustrations of some of the steps of scientific methods:

Observation

Science is empirical and facts are sacred to scientists. Facts are observable. So science starts with one observation and ends with more observations. It is important that experiments and activities must generate opportunities of observations to learners. While carrying out experiments and activities, asking the class a simple question skillfully, "What do you observe?" may provoke thinking and may generate divergent answers since it is open-ended. If the teacher draws attention of learners towards few questions, and later prompts students for more observations, such questions generate guided observation. Let us see the following classroom situations as example.

Table 7.2 Example: Burning candle inside the cylinder

Traditional way		Constructivist way	
Teacher	Keeps a lighted candle in a gas jar of oxygen (Fig. 7.2) and asks, "What do you observe ?"	**Teacher**	Keeps a burning candle in a deflagrating spoon (Fig. 7.3) and asks the class, "If I introduce this into a jar of oxygen, what do you think would happen?"

Traditional way		Constructivist way	
Student	Candle burns more brightly.		Students come with different predictions.
Teacher	So, oxygen is a supporter of combustion.  **Fig. 7.2** *Burning candle inside the cylinder*	**Teacher**	Continues, "Let us see."  **Fig. 7.3** *Burning candle outside the cylinder*
		Student 1	Candle burns more brightly.
		Teacher	What happened to the gas?
		Student 2	Nothing. The gas does not burn.
		Teacher	Suppose I introduce a burning paper/match-stick. What may happen?
		Student 3	That may also burn brightly.
		Teacher	What is your conclusion?
		Student 4	Oxygen is a supporter of combustion.
		Student 5	Yes, and oxygen is not a combustible gas.
		Teacher	You are right. Oxygen is a supporter of combustion and not a combustible gas.

ACTIVITY 7.3

Which of the above situations represent open-ended observation and guided observation, respectively? Which approach indicates a pedagogical shift? Justify your answer and discuss in the class.

ACTIVITY 7.4

Concentrated HNO_3 is dropped on copper turnings. How will you draw the attention of students to the following, creating a constructivist situation in the class

1. Colour of the gas
2. Nature of the gas: dense/thin
3. Odour of the gas
4. Colour of the solution
5. Temperature changes
6. Similar reactions possible, etc.

ACTIVITY 7.5

A student who observes that the mesh windows of a chemistry laboratory are more rusted than those of a classroom, starts wondering, "why is this difference?"

- Is it because of the chemicals?
- Is it because of more heat?
- Is it because of fumes?

Such questions require probing and can lead to further explorations of ideas. Similarly write an observation which leads to further questions.

Observation (s) ______________________________

____

Questions

1.
2.
3.
4.

Hypothesis

Humans are naturally curious and like to find explanation for observations made. Explanations are given using the known facts. But some observations cannot be explained since we do not have 'facts' to apply. In such cases some models (theories) are proposed to explain the observed set of facts. These theories invoke the 'unobserved' to explain the observed. Theories require test of experimental verification before being accepted as laws. For example— *kinetic theory, atomic theory,* etc.

Similarly some observations are reasoned out using some intelligent guesses. They are called hypotheses. These hypotheses may only explain a few observations or most of the observations. The one which explains most observations most satisfactorily is chosen as the best hypothesis.

Example : Fountain Experiment with NH_3

Traditional way	Constructivist way
Fountain experiment is performed by the teacher and she informs the class that the ammonia gas is highly soluble in water. (Fig. 7.4)	Teacher performs the experiment. She asks students, what do they observe. **Student 1**: Water enters into the flask as a fountain. **Teacher**: Why does water enter into the flask as a fountain? She asks students to give reasons for their answers. **Student 2**: Gas goes out and water comes in. **Student 3**: Outside pressure is more than inside pressure. **Student 1**: Gas reacts with water. **Student 4**: Gas dissolves in water and so pressure inside becomes less and so water rushes in. **Student 5**: Water rushes through the tube as fountain, because a jet tube is used.

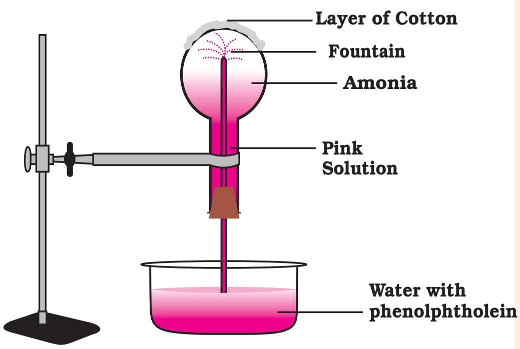


Fig.7.4 *Fountain experiment to prove the high solubility of ammonia in water*

Now teacher has to discuss each answer and show how the 4th hypothesis is right. The following procedure is adopted.

1. The experiment is repeated with air in the flask instead of NH_3. Water does not enter in. So first hypothesis is wrong.
2. The above experiment also disproves second hypothesis.
3. The experiment is repeated with Cl_2 instead of NH_3. Water does not enter in the flask. So, third hypothesis is wrong.
4. The experiment is repeated with HCl instead of NH_3 which is also soluble in water. Water rushes inside showing that fourth hypothesis is right.
5. The experiment can be repeated using a narrow mouth bottle instead of a flask. Water still gushes inside showing that the fifth hypothesis is also wrong.

ACTIVITY 7.6

How can you convert a classroom activity on the topic *Colloids* to a situation generating a variety of hypotheses? Discuss with your classmates, how you would establish the correct hypothesis.

Experimentation

Experiments should be integrated with the theory part of the science. It should not be treated in a piecemeal manner. Let us now see how experiments on *displacement reaction* may be carried out with the traditional and constructivist approach with the help of the following activity:

Traditional way: The teacher may take an aqueous solution of $CuSO_4$ in a beaker and dip a strip of Zn in it. She leaves the beaker undisturbed for sometime. Then, the teacher asks the students, what do you observe?

The students may reply that blue colour of the solution fades and a brown coating appears on the strip of Zn. Teacher then explains that this is because zinc is more reactive than copper, it displaces copper from its salt solution.

Constructivist Way: The teacher may take two beakers and label them as 'A' and 'B'. In beaker 'A,' she takes aqueous solution of $CuSO_4$ and calls a student to dip a Zn strip in it. In beaker 'B,' aqueous solution of $AgNO_3$ is taken and a Cu strip is dipped in it. She suggests to the class, "Let us keep the two beakers undisturbed for sometime and observe what happens."

Students observe that blue colour of the solution fades and brown coating appears on Zn strip in beaker 'A.' She draws attention of students to beaker 'B.'

Students observe and state that colour of solution changes from colourless to blue and a shiny coating appears on Cu strip.

Student 1: Why do these changes occur in beakers 'A' and 'B'?
Teacher encourages the class to think about it. Students come up with some responses.

Student 2: I think that Zn being more reactive than Cu. Therefore, Zn displaces Cu from $CuSO_4$.

Teacher: Yes, you are right. And Cu being more reactive than Ag, displaces it from $AgNO_3$. What type of reaction do you think is occurring in this activity?

Student 3: Displacement reaction.

Teacher: Which metal in this experiment is most reactive? How can we arrange the three metals involved in this activity in the order of their decreasing reactivity?

Student 2: Zn > Cu > Ag.

Teacher: Now, think about a situation, where we can store a solution of $ZnSO_4$ in a copper container.

Student 4: Yes, we can. Because it will not react with copper.

Teacher: Do you now think that the reaction taking place is a displacement reaction? Here a more reactive metal displaces a lesser reactive one from its salt solution.

Student 5: Yes, now I understand well.

Student 2: Can we arrange metals on this basis in the order of their decreasing reactivity?

Student 6: Yes, I have seen it in the book. Various metals are arranged as reactivity series. Because of reactivity, it is safe to store a salt solution of a metal in a container made of a lesser reactive metal.

ACTIVITY 7.7

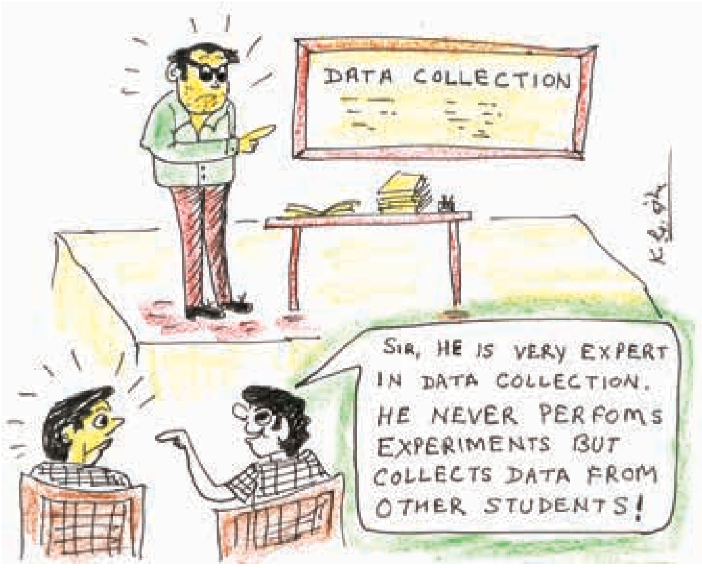
Design an activity on identification of acids/bases by using an indicator. How will you illustrate it in both the traditional and constructivist way. Share your work with your classmates. Do you consider one approach better than the other? Discuss it giving your justification.

Data Collection

Most of the explanations/solutions are obtained by doing experiments. In cases where experimentation is not possible the data is collected using reference/resource materials. A survey method involves such a collection of data and observing a pattern among the data, so that a rule (concept) may be formed. The source of the data has to be reliable or authentic. The conditions also have to be specified under which such a data is collected, because the validity of generalisation depends upon the validity of the data.

Data

- Measure volume of one litre of different liquids such as water, milk, oil, glycerene, etc.
- Find out the mass of each liquid. Is the mass of equal volume of all liquids same?
- Determine density of each liquid. Which liquid has highest density?
- Arrange the liquids in decreasing order of density.



ACTIVITY 7.8

Following is an example of activity that can be conducted in the class engaging students in teaching–learning of science. Read it critically in the light of the discussion on pedagogical shift and give your suggestions on how would you engage students actively in inquiry through this activity? There might be multiple ways of engaging the learners in inquiry through these activities. Share your views in the class on this statement in the context of this activity.

Concept

Solubility of common salt/sugar in water

Observation

1. If sugar is added into still water, it takes longer time for dissolution.
2. Salt/Sugar dissolves fast in water on stirring or heating the mixture.

Inquiry

1. What is the reason for fast dissolution of salt/sugar in water?
2. Whether volume of solvent increases on forming solution?

Hypothesis

1. On increasing kinetic energy of particles, either by stirring or by increasing temperature, the components of solution intermix fast.
2. Volume of solution increases, because solute particles also occupy space.

Experimentation

1. Take 100 ml of water each in three beakers 'A,' 'B' and 'C.'
2. Put one teaspoonful of salt/sugar in each beaker.

3. Do not disturb beaker 'A.'
4. Stir the mixture of beaker 'B' with the help of a glass rod.
5. Heat the mixture of beaker 'C' on the tripod stand with the help of spirit lamp/burner.
6. Record the time for complete dissolution of salt/sugar in beaker 'A,' 'B' and 'C'.
7. Measure the volume of solutions in beakers 'A,' 'B' and 'C' with the help of a measuring cylinder.

Conclusion

1. Complete dissolution of salt/sugar in beaker C takes the least time. Time taken for complete dissolution of salt/sugar in beaker 'A' is maximum out of the three cases.
2. Volume of solution in each case remains 100 mL.

Comments

Hypothesis no. 1 is correct, but hypothesis no. 2 is incorrect, since, there is no change in the volume of solvent on forming solution. There is a need to alter the hypothesis no. 2. The correct reason is that the solute particles occupy the spaces available in the solvent itself, called intermolecular spaces. No new space is occupied by the solute particles.

As we have discussed above, NCF-2005 envisages teaching-learning of science in schools to be learner-centred and process and inquiry oriented. The teacher preparation programmes can also take a message from these examples to encourage construction of experiential learning environments.

National Curriculum Framework for Teacher Education (NCFTE-2009) also recommends adoption of process-based teacher education. The student-teacher should also be provided with ample opportunities for self-learning, reflection and assimilation. In addition and more importantly, there should be scope for articulation of new ideas, ability to enhance thinking and work efficiently in groups.

One understands the intricacies of nature of science by the process of observation and experimentation. To inculcate scientific temper to the learner, the science teacher has to facilitate the learners to think like a scientist and get actively involved in the inquiry through learning process. **The learners should be encouraged to question and learn to observe carefully, interpret their observations to understand the situation. This motivates the learners to learn more and more themselves and to explore the world around them.**

7.3 DEMOCRATISING SCIENCE LEARNING: CRITICAL PEDAGOGY

Critical Pedagogy is child-centered pedagogy. It facilitates collective decision-making through open-mindedness and by encouraging and recognising multiple views of the learners. It emphasises to move beyond authoritative role of the teacher by promoting sharing of power with the learners by encouraging critical thinking and commitment to democratic form of interaction. **It is a pedagogy that takes into accounts the experiences and perception of learners and helps them to learn in a fear free and independent form.**

In the context of critical pedagogy, NCF-2005 recommends following guidelines:

- Participatory learning and teaching, emotion and experiences need to have a definite and valued place in the classroom.
- **Children need to be made aware that their experiences and perceptions are important.** They should be encouraged to develop the mental skills needed to think and reason independently. It is important to value what learners learn out of school— their capacities, learning abilities and knowledge base and bring them to schools in order to further enhance the learning process. This is all the more important for the children of underprivileged class.
- Children are critical observers of their own conditions and needs. They should actively participate in discussions and problem-solving related to their education and future opportunities.
- Children are not just young people for whom adults should devise solutions. Teacher's engagement with children is critical in the classroom, because it has the power to define whose knowledge will become part of the school-related knowledge and whose voice will shape it.
- When children and teachers share and reflect on their individual and collective experiences without fear of judgment, it gives them opportunities to learn about others who may not be a part of their own social reality. This enables them to understand and relate to differences instead of fearing them. If children's social experiences are to be brought into the classroom, it is inevitable that issues of conflict will need to be addressed. Conflict is an inescapable part of children's lives. To use conflict as a pedagogic

strategy is to enable children to deal with conflict and facilitate awareness of its nature and its role in their lives.

- A pedagogy that is sensitive to gender, class, castes and global inequalities is one that does not merely affirm different individuals and collective experiences but also locates them within larger structures of power and raises questions, such as, "Who is allowed to speak for whom? Whose knowledge is most valued?" This requires different strategies for different learners. For example, encouraging speaking up in class may be important for some children, while for others it may be learning to listen to others.
- Learning to question the received knowledge critically whether it is found in a 'biased' textbook, or other literary sources in their own environments, can be facilitated by encouraging learners to compare, think and communicate about elements that exist in their own environment.
- Repository of knowledge exist in different mediums, hence all these forms, whether television programmes, advertisements, songs, paintings, etc. need to be brought to create a dynamic interaction among learners themselves.

Thus, we observe that critical pedagogy provides an opportunity to reflect critically on issues in terms of their political, social, economical and moral aspects. It entails the acceptance of multiple views on social issues and a commitment to democratic form of interaction. This is important in view of the multiple contexts in which our school functions.

7.3.1 Critical pedagogy and role of teachers

- The role of teachers is to provide a safe space for children to express themselves, and simultaneously to build in certain form of interactions.
- Teachers need to step out of the role of 'moral authority' and learn to listen with empathy and without judgment, and to enable children to listen to each other.
- While consolidating and constructively stretching the limits of children's understanding, they need to be conscious of how differences are expressed.
- An atmosphere of trust would make the classroom a safe space, where children can share experiences, where conflict can be acknowledged and constructively questioned, and where resolutions, however tentative can be mutually worked out.

In particular, for girls and children from underprivileged social groups, schools and classrooms should be spacious for discussing processes of decision-making, for questioning the basis of their decision, and for making informed choices. Teachers need to cultivate an understanding of the cultural and socio-economic diversity that learners bring with them to school.

ACTIVITY 7.9

From the perspective of teaching-learning of physical science, discuss how does classroom interaction in critical pedagogy not only uses democratic principles but also helps in inculcating democratic values.

7.4 PEDAGOGICAL SHIFT: PLANNING TEACHING-LEARNING EXPERIENCES

In the light of the brief introduction of various shifts discussed above, we can conclude that there are so many aspects that should be considered for planning effective teaching-learning environments. It is important to listen to learners and encourage them to engage in assessing and evaluating their own ideas. There is an urgent need to build-up activities and strategies that are effective not just for a range of science content areas but also productive for exploring and challenging learners' conceptions. Also the importance of the socio-cultural perspective that focuses on the way learners' differentiation and cultural backgrounds shaping their learning experience, cannot be undermined. For the learning environments to be effective, there are aspects other than those discussed above. For example, learners' willingness to engage with learning, the effect of assessment, nature of school environment, learners' perception about relevance of science in their lives, etc.

Planning for the teaching-learning of physical sciences is discussed in detail in Chapter 12. However, it is important to reflect upon the shift in planning that can be envisaged in the light of the discussion so far. Until very recent times, teachers used to plan for the year at the end of one year or at the beginning of the school year, putting a lot of efforts in planning for interruptions such as sports days and other vacations, carefully deciding about the content to be covered throughout the year, dividing the content into various week-based units and chunks, getting down to specific topics, examination schedules, etc. This was done when learners' minds were considered as empty vessels to be filled by the teachers' imparted information. Not only this, there had been a centralised planning of the sort explained here and sending all these centralised plans to be followed by all the teachers in different schools of the state/region, so that there is uniformity in what is going on in the classrooms across the state/region. If that sort of plan could not be followed for any reason, actions were taken against the teachers.

This sort of centralised action on the teachers' role in the classroom still prevailing at some places, however, is to be done away in the interest of learners.

Teachers need to develop the ability to plan 'units' of four or five lessons for each topic. **They need to understand how to develop lesson design, so that learners are challenged to think and try out what they are learning and not simply repeating what is told to them.** In fact teachers could also consider involving learners in planning the class work. Such variety can bring tremendous richness to the classroom processes.

The paradigm shifts discussed above have however encouraged the teacher to shift the focus from traditional to the constructivist approach. This change in focus has also given rise to some confusion on the role and approaches of planning. For example, starting to plan from where the learner is at present – this can be confused with going with a terrifying question about how to start with thirty plus children in a class having different experiences. In the first go, it seems impractical and scary for even the most experienced teachers. So what does planning means now? Before discussing the aspects of planning, we can have a look at the change in the nature of questions that needs to be answered before and after the shift.

7.4.1 Planning teaching-learning: Before shift

- What will I be teaching?
- How much do I know the syllabus?
- How do I prepare the students for the upcoming exams?
- What serialisation of the concepts should I consider?
- What objectives are to be used for measuring performance of the students?
- When and how to plan the measurement of the learning integrating with teaching experiences with respect to my lesson plans?
- How do I control the students?
- How can the knowledge I have to transmit be the best?
- Who are the students who have succeeded?

7.4.2 Planning teaching-learning: After shift

Following are the respective changes in the questions that need to be answered in order to plan teaching-learning process in physical science:

- What are the learning needs and previous experiences of my learners?
- How much I am acquainted with the learning needs of my learners?
- How do I facilitate each learner's learning?
- How do I incorporate the differential learning pace of my learners?
- What is the progress of the learner as compared to her previous learning experiences?
- How do I analyse the present learning evidences to plan further learning experiences for the learners?
- How do I facilitate and support each learner in learning?
- How best can knowledge be constructed by all learners?
- What next?

The shift to the new frameworks also means that the teacher obviously has a lot of liberty in choosing the planning approaches and strategies. This liberty of planning provides flexibility to the teacher to consider students' learning needs; their existing concepts; the context of their learning; local and national needs; nature of curriculum; etc. in designing teaching-learning experiences.

7.4.3 Planning teaching-learning: Examples

Some of the shifts can be seen in the following examples in the learning area of *Properties of Matter*.

Example 1

Statement 1. A teacher can teach the properties of matter on the basis of previous knowledge of students about solids, liquids and gases taught during previous classes.

Statement 2. A teaching-learning process can be designed in the learning area of *Properties of Matter* based upon some understanding of solids, liquids, and gases as explored in previous classes. This lesson needs a brief introduction of matter.

We can clearly see the difference in the two statements above. Whereas in the first statement the assumption is about pouring knowledge into the mind of students, the second statement is about designing teaching-learning experiences for the students which are based on their previous explorations to facilitate the meaning-making process.

Example 2

In the following two statements, we can see that the focus is shifting towards engaging the learner in the process of scientific inquiry. Moreover the learner has been given the liberty of giving the explanations in her preferred style. She is not being tested on the basis of teacher's preconceived ideas about the learner's performance.

Statement 1. Learning goal: the teacher will demonstrate properties of objects and materials.

Statement 2. Learning goal: learners will be facilitated to plan, conduct investigation to find answer of self formulated question, use data, construct a reasonable explanation, communicate investigations and explanations in their preferred style to determine the properties of objects and materials.

Example 3

The inquiry question, "How can we describe the physical properties and the molecular structure of matter?" can be taken up in the class in many forms.

A pedagogical shift in the approaches can be seen in the following way. We can say that the approach 1 is directive in nature and approach 2 is inclusive in nature.

Approach 1

After the completion of the class, the student will be able to

- recall that objects are made up of material;
- explain that materials are composed of molecules which cannot be seen with naked eyes; and
- interpret that if the material is reduced in size, physical properties remain the same.

Approach 2

Learning objective : Learners investigate and understand that objects are made up of materials that can be described by their physical properties.

Key concepts include

- Objects are made up of material/s
- Materials are composed of molecules that cannot be seen with naked eyes.
- If material is reduced in size, physical properties remain the same.

Example 4

A shift towards designing learning experiences, ensuring learners' engagement can be seen as depicted below. Moreover in the second approach we can see more democratic involvement of the learners in maximum possible forms. We can also see a reflection of critical pedagogy in the second approach.

Approach 1

The teacher makes a diagram of three boxes on the blackboard depicting circular parts with varying distances between them as a representation of molecules of solid, liquid and gas, respectively (Fig. 7.5). Learners very quietly draw these in their notebooks and are able to make those diagrams in the examination.

Approach 2

To start, teacher facilitates the class to form different groups of four to five students. Teams are made up of students with varying academic abilities, and socio-economic-cultural backgrounds. Teacher asks them to stand up and move very close together and tells them to pretend they are molecules that have been pushed together. Teacher tells them to jump up and down, move around, etc. Then the teacher encourages them to describe, what they think is happening and how do they feel pretending as if they are the molecules of a solid. Then the teacher increases the distance between the students and they move slightly apart. Now the teacher encourages the children to try different movements and compare this to their prior movement. The students now feel as if they are the molecules of a liquid. Lastly, they are spread out completely, again trying different movements around the room for a minute without touching each other. This is how they can feel themselves to be molecules of a gas.

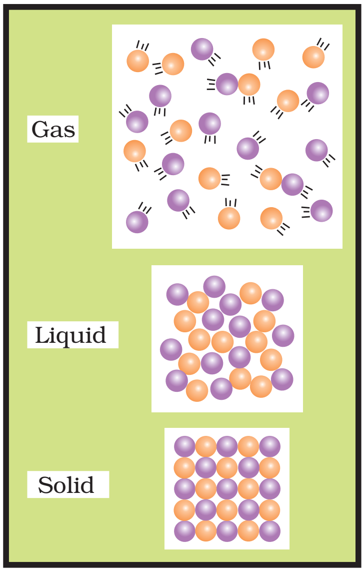


***Fig. 7.5** Molecules of a solid, a liquid, and a gas*

Example 5

Approach 1

Students are evaluated on the basis of their performance on paper-pencil test at the end of the academic session or term. The question paper is based upon the set of objectives on the topic solid, liquid and gas. The student are expected to write the correct answers to the questions. The teacher is given a marking scheme or a key with the break up of marks and the correct answers. The teacher matches the correct answers and gives marks accordingly.

Approach 2

Table 7.3 Assessment out of 100 points

Learning Indicator	**Grades**		
(LI)	**A**	**B**	**C**
1. Learner's participation in the classroom proceedings	• Learner is fully engaged and contributing to the classroom proceedings and activities.	• Learner is participating, but not actively engaged in lesson	• Learner is not engaged in lesson

Learning Indicator	Grades		
(LI)	**A**	**B**	**C**
2. Naming and explaining three states of matter	• Learner can identify all three states of matter and identify their basic properties.	• Learner can identify all three states of matter and describe some of their basic properties.	• Learner can identify all three states of matter, however, can describe only a few of their basic properties.
3. Answering questions orally or in written form	• Learner is able to answer most or all of the questions from classroom proceedings.	• Learner is able to answer some questions from classroom proceedings.	• Learner is able to answer only a few questions from classroom proceedings.
4. Differentiating the structure of solid, liquid, or gas	• Learner understands that solid, liquid and gas have different structures, and can relate to them.	• Learner identifies that solid, liquid and gas have different structures, but cannot relate to them properly.	• Learner cannot relate structure and object's classification as a solid, liquid or gas

ACTIVITY 7.10

How can you bring pedagogical shift in designing various teaching-learning experiences on the line of examples given above on the following topics?

(i) *Wave Optics*

(ii) *Electrochemistry*

(iii) *Reflection and Refraction of Light*. Write down about them sharing your ideas in a group. Exchange your work with other groups and critically examine each other's ideas.

7.5 PEDAGOGICAL SHIFT: INCLUSION

A policy of inclusion needs to be implemented in all aspects of teaching-learning of science. A pedagogical shift is required to identify diverse capabilities and talent of all learners. Let us now discuss it in detail.

7.5.1 Science curriculum

Equal opportunities and full participation to all learners including learners with special needs, and learners learning with different paces should be provided in the theoretical and practical activities conducted in science classes. Through adaptation of the curriculum (what learners learn) and modification of the approaches of teaching-learning (how learners learn), access to science curriculum can be made possible for all these learners.

Accommodations in the general curriculum do not change the learning level of the curriculum or the performance criteria. With accommodations, the learners are working on the same learning objectives and content as the other learners; however, how the learners learn and the ways they produce evidences of what they have learned may be different from that of their peers. Accommodations are not intended to take place in learning of the subject matter or development of basic skills. Instead they provide support in various ways to the learners with learning problems to express their knowledge. Accommodations can include changes in (a) presentation and/or response format and procedures, (b) teaching-learning strategies, (c) time and scheduling, (d) environment, (e) equipment and (f) architectures, etc. without changing the central theme/objectives of the curriculum contents.

Modifications are substantial changes in what a learner is expected to learn and demonstrate. Changes may be made at teaching-learning level, in the content, or in the performance criteria. Such changes are made to provide a learner with meaningful and productive learning experiences, environments, and assessments that are based on her needs and abilities. Modifications require a change in type and amount of work expected from the learners. For example, a learner may be working at a lower level than other learner in the class or the learner may still working on a skill upon which other learners have already acquired proficiency.

7.5.2 Diversity in class

Inclusion is centrally a pedagogical issue, since it creates the most significant barrier to learning and exclusion for many learners. These barriers to learning arise from various interlocking parts of the curriculum and pedagogy, such as the content of learning programmes; the language and medium of teaching and learning; the management and organisation of classrooms; learning style and pace; time frames for completion of curricula; the materials and equipments, that have been available for conduct of theoretical and practical sessions; and assessment tools and techniques.

It is a clear pedagogical principle that teacher should use a variety of approaches and strategies that promote meaningful learning, active participation of all learners, recognition of their knowledge and previous personal experiences, autonomy in their learning process and self control and collaboration among learners. A number of assistive and adaptive devices such as Braille equipments, adapted science kits, hearing aids, communication aids, mobility aids,

Fig. 7.6 *Reading aids for learners with visual impairment*

reading and writing aids, etc. are required to be used in the classroom for transaction of curriculum contents as per the needs of the students.

The pedagogical shift in science education should be based on giving respect and value to individual differences and providing opportunities for scientific exploration, manipulation, experimentation and discovery of scientific phenomena which ultimately enhance the personal development of every learner. Traditionally, educational differences have been ignored and parallel structures and educational approaches have been developed for different groups of learners. For inclusive education, the present pedagogical approaches should meet the educational needs of each and every learner including learners learning with different paces and the learners with special educational needs group.

7.5.3 Approaches

The educational approaches should be based on heterogeneity in the classroom instead of homogeneity. The educational approaches based on homogeneity have taken us to perceive diversity from normative criteria. Those learners who do not confirm to standard established norms are considered different having difficulties and anomalies and engaged with differentiated programmes and different approaches. Since diversity is a part of what we call ‘normal,’ our educational approaches should be as per the learners’ capabilities, interests, motivations and experiences that are unique and individual. Some effective strategies to answer these diversities are: curriculum adaptation strategies, teaching-learning strategies to accommodate diversity such as outcome-based education, project approach multisensorial (Visual-Auditory-Kinesthetic-Tactile-VAKT) approach, teaching-learning organisation by providing working spaces, working in groups, and collaborative learning, peer tutoring, team teaching, cross class groupings, multi-age groupings, self learning guides, etc. or combination of approaches to meet day-to-day challenges in the classrooms. Prior to teaching-learning of a particular topic on physical science to learners with special educational needs, it is advisable to develop Individualised Education Programme (IEPs) based on Present Level of Performances (PLOP) on the topic to be transacted in the class. The communication in science should not ignore the ‘Total Communication’ approach, where a variety of methods such as speech and other supplementary communication techniques like sign language, finger spelling, cued speech, etc. are used to communicate with the students. Similarly, Alternative and Augmentative Communication (AAC) systems with or without an external aid assist in communicating to the students having difficulties in comprehension and expression.

ACTIVITY 7.11

Inclusion is all about providing effective learning opportunities to all learners. Share your views in the class on various ways of providing such opportunities to all.

7.5.4 Information and Communication Technology (ICT)

ICT can be made accessible to the learners with special educational needs by innovations and adaptations in the basic functional units of ICT such as ‘microchips’ and ‘software packages’. Most of the information is disseminated either in the visual or in audio format restricting its accessibility to students with sensory impairments. For exploration and manipulation of electronic gadgets and hardware, high level motor planning, coordination and execution are required in the individual which is lacking in most of the learners with special needs like in cases of cerebral palsy and other neurological and locomotor disabilities; dysgraphia, dyspraxia, mental retardation, visual impairment, mental illness, leprosy cured and in multiple disabilities conditions. Production of adapted peripherals and add-on devices with indigenous softwares are being developed to suit the needs and requirements of the learners with special educational needs. Few examples of such devices are writing aids, communication aids— *swarlipi*, gadgets for manipulating computer; speech synthesiser; electronic Braille shorthand machine, Voice Output Communication Aid (VOCA), Digital Accessible Information System (DAIS), Digital books, screen reading softwares, text to speech engine, vibro-tactile and electro-tactile aids, etc. for differential needs of learners with special educational needs with respect to ICT.

Project 7.1
Search on the internet to get detailed information about the devices that can be used by the learners with special educational needs.

7.5.5 Professional development

Although pre-service and in-service teachers' training programmes are now having contents related to education of learners with special educational needs, the teaching in inclusive classrooms where such learners are also studying is not properly practised in a real inclusive setting. Due to this reason, the educators lack proficiency in different aspects of teaching–learning like attending the needs of diverse groups, curriculum adaptation, transaction of contents as per the needs of all learners, differential evaluation, etc. Preparing Individualised Education Plans (IEPs) and incorporating these IEPs in/parallel to regular classroom teaching-learning is another big challenge for the teachers. Special teachers are trained in education for particular types of disability and in the case where special teachers for other disabilities such as for visual or hearing disability are placed, may not find themselves skillful for meeting the educational needs of the learners with other types of disabilities. It is imperative that the appropriate attitudes and skills must be developed in teachers in their precious periods of training. The interactive impacts of multiple disabilities on education of these students cause big challenge for teachers, because neither a single/isolated strategy nor combinations of strategies work and so the educator must be creative enough to take such challenges. This calls for intensive orientation of general teachers as well as appointment of well qualified and competent special teachers in inclusive schools.

7.6 SUMMARY

The movement towards pedagogical shift in teaching-learning of physical science can be augmented by critically focusing among the teachers and learners, the constraining influences and promoting collaborative efforts aimed at overpowering them. For any qualitative change from the present situation of science education, a shift in pedagogy from a fixed body of knowledge to the process of constructing knowledge is urgently required.

It is important to encourage inventiveness, creativity and critical thinking in learner rather than developing competency. Rote memorisation should be discouraged. Inquiry skills should be supported by language, design of conducive learning environment and laboratory work. **It is also important to allow students making errors and mistakes as it is an integral part of the learning process and remove the fear of not achiving 'full marks' or 'first prize'. Participation of all learners in various aspects of teaching-learning should be ensured.** Schools should place much greater emphasis on various curricular activities aimed at stimulating investigative ability, inventiveness and creativity even if these are not part of the external examination system.

Teacher should consider herself an active member of a group of persons who makes conscious efforts for updating the pedagogy, so that it is relevant to changing societal needs and personal needs of learners. **Providing flexibility to the work of teacher and support of school authorities is essential to work towards pedagogical shift.** Teacher should articulate their ideas to administrators. She should feel empowered to put forth her point of view on various pedagogical issues to the concerned authority with conviction and in a persuasive manner.

EXERCISES

7.1 Why do we feel the need of pedagogical shift in physical science?

7.2 Illustrate different dimensions of pedagogical shifts cited in this chapter taking examples from different curricular areas in physical science.

7.3 Discuss how do you justify science as 'a process of constructing knowledge'.

7.4 What relationship or similarity do you see between the shift in nature of science and our understanding of nature of knowledge construction?

7.5 Discuss the role of teachers and learners in constructing knowledge of physical science citing examples.

7.6 'Construction of knowledge draws heavily from the experiences provided in the learning context.' Explain.

7.7 What are the different ways in which 'observation' can influence 'scientific inquiry.' Explain it taking an example from physics.

7.8 Describe a learning context which can lead the learner to 'hypothesise' a model.

7.9 How would you make your students observe better? Design questions taking any topic in physics or in chemistry which calls for
(a) guided observation
(b) open-ended observation

7.10 In order to facilitate the learners to construct the concept that when an object is placed between the optical centre of the convex lens and *F*, the image is magnified. How would you lead them into inquiry?

7.11 'Learning of scientific inquiry should be well planned and can not be expected as side effect of various approaches of teaching-learning in science.' Critically examine this statement.

7.12 How is science curriculum related with science learning environment? How can a teacher make various adjustments in curriculum to consider all learners' interest and their cultural backgrounds?

7.13 Pedagogical shift in science learning is multi-pronged. How can you integrate various dimensions in pedagogical shift in science learning? Critically reflect on your own understanding on this issue.

7.14 What do you mean by critical pedagogy? What are the recommendation of NCF-2005 regarding this? Discuss the role of the science teacher in facilitating critical pedagogy supporting with an example of physical science.

7.15 Make a list of the guiding principles that you can identify from this chapter on pedagogical shift for planning teaching-learning experiences of a child in science classroom. Do you see role of learners' experiences outside the science classroom in designing those experiences. Discuss.

7.16 What difference does it make in pedagogy of physical science when we see nature of science in terms of scientific method and in terms of scientific inquiry with no particular set of steps or procedure? Explain.

7.17 Discuss how will you ensure a pedagogy that is sensitive to gender, class, and learners with special educational needs in science learning environment ?

7.18 What is the meaning of inclusive classroom with reference to physical science? Discuss various pedagogical aspects of inclusive education. Give some examples of alternate physical science learning environments that you can design for the learners with special educational needs.

Chapter 8

Approaches and Strategies for Learning Physical Science

8.1 INTRODUCTION

Learning science is related to the aims of teaching–learning of science, students' and teachers' conceptions of science content, nature of the science concept and nature of learning process. In traditional learning process, the teacher transmits the facts and assumes the students as passive receptors of knowledge. This teaching-learning process is **teacher-centred approach**. Students view science learning as accumulation of pre–fabricated knowledge or fact which is to be stored in memory by the process of rote learning. This passive view of learning forbids the students to construct their knowledge and understand the concepts to apply them in their day-to-day life. Some of the features of this approach are

- Learning is a passive process.
- Learners are not actively involved in the teaching-learning process.
- Focus is on the teacher and teaching strategies.
- Teacher predominantly uses lectures to provide explanation to learners.
- It is assumed that teacher knows everything and learners do not know anything.
- The teacher demonstrates and the learners observe.
- The teacher enforces his authority and the learners obey it.

Teacher-centred approach of learning is not accepted by many because of its inadequacy to develop important intellectual capability in students, such as decision-making and problem solving, creativity, and critical thinking skills. Gradually the understandings about learning of science has changed with the developments in psychology and epistemology. Inclusion of newer models of learning from psychologists like J.S. Bruner, David P. Ausubel and Jean Piaget have prompted the science education community to focus on how students learn science and it has started viewing teaching-learning of science from a transmission model to construction of knowledge by the students.

The NCF-2005 emphasises **learner-centred approach** to achieve the objective of the curriculum. The curricular content and its transaction must be relevant to the learners and should help them to become constructors of new knowledge and lifelong learners. Therefore, a pedagogical shift is required from teacher-centred to learner-centred teaching-learning process. We have already discussed about this shift in Chapter 7, i.e. *Pedagogical Shift in Physical Science*. **There is a need to move from a predetermined set of outcomes and skills to the set that enable learners to develop explanatory reasoning, and critical thinking and inquiry skills.**

Let us first have an overview on the historical background of the development of various theories and approaches of learning.

8.2 SCENARIO FROM 1950–1980

Until the 1950s, researches on teaching focused on two themes— firstly, the method 'experiments' where researchers compared the relative merits of using one method of teaching a particular subject with another method and secondly, exploring the personal characteristics of a good teacher. By the 1960s, it was increasingly recognised that teaching could not be described or prescribed in terms of standardised methods. It was also accepted that teachers could not be distinguished by any kind of distinctive personality alone. It was realised that to understand teaching, one needs to study what happens in the classroom.

During 1960 to 1980, the movement for knowing how students learn science began. Bruner (1961) for the first time identified the characteristics of a concept and proposed the *concept attainment model*. Bruner model advocates that a child is said to have attained a concept, if she can apply the concept in unfamiliar situations and arrive at valid conclusions. 'Discovery learning' was also pioneered by Bruner which was used as the foundation for curriculum development during 1960s to the 1980s. He emphasised on helping students 'how to learn'.

Ausubel also tried to understand the learning process. He was among the first to describe the importance of the knowledge students carry to the classroom. He proposed that students are not devoid of ideas. Their experiential knowledge have a profound effect on how students learn in the class. **Meaningful learning occurs when new information is linked with existing concepts and integrated into what the learner already understands.** Students can make connections between what they learn in science classrooms and what they already know. We shall discuss on Ausubel's theory of learning in little detail in section 8.9 of this chapter.

In order to understand how children learn science, it is important to consider the development of children's cognitive abilities and skills. Through extensive and intensive empirical evidences, Piaget proposed 'stage dependent' theory where the mental growth of a child goes through four discernible stages. These are hierarchical stages. He associated each stage with a particular age range. The age associated with each stage is individual dependent, i.e. few may not reach the last stage of cognitive development. The stages are

(i) The sensory motor stage (0–2 years)
(ii) The pre-operational stage (2–7 years)
(iii) The concrete stage (7–11 years)
(iv) The formal stage (11–15 years)

Piaget believed that learning is strongly influenced by the learners' developmental stages. Learners move through identifiable stages of physical, intellectual, emotional and social growth that determine what can be learned and with what depth of understanding. Learners learn best when they are at the proximal stage of development. According to Piaget, 'organisation of concepts in the mind of a learner goes through four cognitive processes— *schema* (organised mental representation of thought), *assimilation, accommodation* and *equilibration'*. These processes are not specific to any stage of cognitive development. An individual expects to understand each new experience in terms of what she already knows by assimilating the experience. Confusion occurs when a learner is unable to assimilate a particular experience to the existing ones. To reach equilibration a learner brings meaning to a new experience through the process of assimilation and accommodation. This process requires an individual to restructure the existing knowledge or reject the existing knowledge and construct entirely new knowledge. These two processes, that is, assimilation and accomodation are important mechanisms in understanding learning of science.

Lev S. Vygotsky argued that learning is social in nature. It is more important to know what a child is capable of learning with good teaching-learning process. He believed that learning can be structured, so children become active learners while teachers or other adults use their advanced knowledge to meaningfully guide the learning. A child learns through social interaction and from peers, older children and adults who know more and have more experience.

By comparing their understanding with that of others and by examining their knowledge against other's knowledge, learners develop new knowledge. Suppose a child is exposed to a concept that she does not understand, she can learn the same concept with instruction and specially if she is given tools or aids which help them to understand. Vygotsky believed that when aided, a child can learn more than if she is left unaided. The difference between what a child can produce unaided and what the child can produce with an aid or good instruction is called the *zone of proximal development*. Thus, when a teacher plans for instruction, she should be aware of the *zone of proximal development* for the child, so that her optimum potential can be realised.

8.3 POST 1980 SCENARIO

The researchers found that in teaching process, the teacher is not important, The learner is not important, but the learning process is important which measures the success of the teaching-learning process. In this process they noticed two important aspects like (i) ascertain what the child knows and (ii) engage her in teaching– learning accordingly. During 1980s and 1990s, constructivist movement gained momentum. A number of studies were conducted by Posner (1982), Driver (1994), Novak (1984) and others on 'how children construct knowledge, and how teacher can provide interventions to help children construct their own concepts.' The study provides some of the basic characteristics of constructivist approach of teaching-learning:

- No child enters a class devoid of concepts. Learning implies the reorganisation of prior concepts of the learners.
- Concepts cannot be instructed, but constructed.
- Every child constructs her knowledge on the basis of her existing knowledge.

- The personal concept of a child about any concept is very much true and valid for her. It may not be scientifically true. The personal concept of the child can be misconception or naive concepts that resist to change or modify.
- Meaningful learning occurs within authentic learning tasks.
- Learning is facilitated in social set-up.

Thus, realising pluristic, contextual and subjective nature of knowledge the teacher can facilitate the learners to construct scientific concept in her own way by actively engaging them in teaching-learning process.

8.4 APPROACHES AND STRATEGIES FOR LEARNING PHYSICAL SCIENCE

Teaching-learning of science is a very complex process. This process involves learner, teacher, teaching-learning materials, suitable approaches and strategies and conducive learning environment leading to meaningful learning. Learner is at the centre of learning process and teacher works as the facilitator of learning (Fig. 8.1).

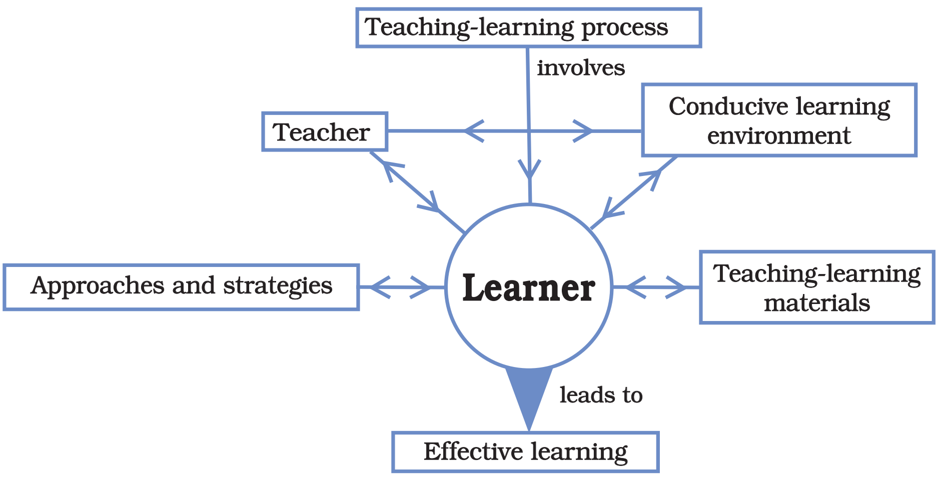


***Fig. 8.1** Teaching-learning process*

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

8.4.1 Difference between approach and strategy

Approach is used in the broader sense. It means a way of thinking and working in a set direction so as to accomplish certain goals. For example, a teacher can use constructivist approach in teaching-learning. This implies that whatever strategies she plans to apply will be guided by the constructivist paradigm. She may adopt any of those innovative teaching-learning strategies and techniques that are guided by this approach.

On the other hand, strategy is a proper and systematic plan which aims to achieve the objective. **In education, strategy means selection of suitable pedagogical processes by means of using appropriate techniques, such that all of these lie in the realm of the approach, the teacher chooses to follow.** Strategies can be changed or modified depending upon teaching-learning situation. In contrast, method of teaching is a set of actions for routine way of teaching-learning. Technique is skill to engage learners in teaching- learning process. It is a certain particular way to accomplish the task/objective.

8.4.2 Different approaches and strategies of learning

All children are capable and eager to learn. They acquire knowledge, skills and understanding through a variety of experiences such as listening, speaking, talking, working with hands, experimenting, observing, discussing, etc. Therefore, a good pedagogy of science must essentially be a judicious mix of a number of approaches giving opportunity to all children to engage in various activities.

There are many factors which affect their learning interest, abilities, motivation and ability to apply knowledge in novel situations. Therefore, approaches of learning should suit to the needs of learners of different background.

Same concepts can be transacted by a number of approaches and strategies by the same teacher. It is also observed that the same topic can be transacted by different approaches and strategies by different teachers. Teacher is the most suitable person to decide on the approach of learning depending on the learner's previous knowledge, need of the situation, context, topic and the capabilities of the learner.

Each learner learns at her own pace and constructs her own knowledge by making her own meaning. The teacher can choose particular approach and strategy which can initiate active participation of the learners in the class.

Teacher, as a facilitator of the learning, needs to create suitable and conducive learning environment for understanding different concepts and for developing scientific attitude in different learners.

There is no best approach or strategy of teaching–learning that is applicable to all situations. Teacher needs to enter into dialogue with learners, negotiate with them, recognise and acknowledge their existing knowledge to think about it. In order to select, improvise or invent the most suitable approach or strategy for learning science, it is important to relate it with their prior knowledge.

8.4.3 Selecting appropriate approach and strategy

All approaches and strategies are workable in certain situation and no approach or strategy is perfect. A particular approach may be workable in one situation, but may fail in another situation. You may think about a set of learning experiences along following lines before deciding about approach and strategy:

- Is there enough scope for involving learners, listening to them, performing activities and experiments, observing, reading, writing, discussing and guiding them for further reading?
- Does it motivate learners to learn?
- Are you comfortable with working on it? Decide about the approach and strategy yourself. Do not take it as suggested by others.
- Does it fulfill the objective of teaching-learning experiences?
- Is it workable in the local situation?

8.4.4 Essential components of all approaches and strategies

The points that must be essentially considered whichever approach and strategy you select are:

- Help children learn *how to learn.*
- Recognise and understand individual differences and their learning styles.

- Be responsive and sensitive to the children's learning needs.
- Active involvement of learners.
- Inquiry and process skills of science should be integral part of teaching-learning of science. Various process skills are ability to define a problem, design an experiment, reason logically, make inferences and draw conclusions based on observations, pose questions and seek their own answers, and communicate clearly.
- Learners' previous knowledge.
- Nature of the concept/topic to be transacted.
- Objective to be achieved.
- Availability of the resources.
- Scope of flexibility in implementing the approach.

8.5 CONSTRUCTIVIST APPROACH

When a teacher enters the class, two questions arise— what to teach? and how to teach? Teacher is expected to be well equipped with the content knowledge as well as pedagogy of physical science. For constructing knowledge of the learner, the teacher may adopt or adapt various strategies of teaching-learning that come under the purview of constructivist pedagogy. Many constructivist pedagogies are available (Brooks and Brooks, 1993; Steffe & Gale, 1995; Larochelle, Bednarz & Garrisson, 1998) which share certain common principles and indicate that eight factors are essential in constructivist pedagogy.

(i) Learning should take place in authentic and real world environment;

(ii) Learning should involve social negotiation and mediation;

(iii) Content and skills should be understood within the framework of learners' prior knowledge;

(iv) Content and skills should be made relevant to the learner;

(v) Students should be assessed formatively, serving to help them acquire further learning experiences;

(vi) Students should be encouraged to become self-regulatory, self-mediated and self-aware of learning;

(vii) Teacher should serve primarily as facilitator of learning, not instructor; and

(viii) Teacher should provide for and encourage multiple perspectives and representations of content.

Over the past three decades, different researchers have proposed a number of teaching models for classroom teaching in the constructivist framework. Implementation of constructivist teaching practices in classroom teaching process is an issue of concern worldwide as it leads to meaningful learning. Structured strategies are followed in different sequential manner by many researchers which result in constructivist teaching models. However, all constructivist teaching models are guided generally by five basic elements (Tolman and Hardy, 1995) which are:

(i) Activating prior knowledge
(ii) Acquiring knowledge
(iii) Understanding knowledge
(iv) Using knowledge
(v) Reflecting on knowledge

There are a number of constructivist teaching models like:

- Nassbaum and Novick Model (1982)
- Generative Learning Model (1985)
- The Ideational Confrontation Model (1985)
- Driver and Oldham Model (1986)
- Niedderer Model (1987)
- Needham's Five Phase Model (1987)
- Neal, Smith and Johnson Model (1990)
- Problem Based Learning Model (1992–1995)
- Glassor and Lalik Model (1993)
- Model proposed by Wittrock (1994)
- Interpretation Construction (ICON) Model (1995)
- Voices Model (1997)
- 5E Model (1997)
- Model proposed by Hewson *et al.* (1999)
- Metacognitive Learning Cycle Model (2000)
- Constructivist Learning Design Model (2001)
- Dual Situated Learning Model (DSLM), (2004)
- Motivational Model of Constructivist-Informed Teaching (2005)

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

(i) Observation
(ii) Interpretation
(iii) Contextualisation
(iv) Cognitive apprenticeship
(v) Collaboration
(vi) Multiple interpretation
(vii) Multiple manifestation

ACTIVITY 8.1

Read page number 19 of the NCF-2005 carefully for the details of the above seven steps. You may visit the website www.ncert.nic.in for this. Design a similar seven steps of learning situation, taking any concept of physical science. Share and discuss your work with your friends.

The upcoming sections of this chapter discusses following models/ approaches/strategis of learning with the help of examples:

(i) 5E learning model
(ii) Collaborative learning approach
(iii) Problem solving approach
(iv) Concept mapping
(v) Experiential learning
(vi) Cognitive conflict
(vii) Inquiry approach
(viii) Analogy strategy

As learners grow older they gather more experiences of the classroom and develop their own strategies of learning for meaningful learning. With a little support from the teacher, they can be facilitated for self-study. We shall also consider this with an example. We then go on to discuss on various aspects of communication in science.

8.6 5E LEARNING MODEL

This is a constructivist model of teaching–learning. The (five) 5Es are — **Engage, Explore, Explain, Elaborate and Evaluate.** In this model, conceptual change can be achieved by using five distinct, but interconnected phases. Let us see it using the concept, *sound is produced by a vibrating body.*

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

The teacher exposes the students to various situations of production of sound by vibrating body and facilitate them to observe carefully. She draws students' attention to following situations.

- Touching the front side of the neck when singing or making a sound
- Allowing to strike a metal bowl, a bell, etc. and touching the object gently and recording their feelings.
- Watching carefully a video film on different musical instruments to know how these are played.
- Speaking her name loudly from the open end of a tin can, other end of which is covered with a stretched balloon and few pieces of grains are kept over it, and observing the movement of grains.


A tin can *eardrum*

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

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

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


Tip of a vibrating tuning fork produces disturbances on water surface

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

- Take a tuning fork and beat it on a hard rubber pad. Do you hear a sound? Now bring the vibrating tuning fork and dip the tip of both the prongs in a glass of water and observe carefully what happens.

- Bring the vibrating tuning fork near a table tennis ball suspended with a thread. What do you observe?

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

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

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

(v) Evaluate: In this stage the teacher sees if the students have attained understanding of concept and knowledge. During the teaching-learning process the teacher adopts continuous and comprehensive assessment of teaching-learning.

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

ACTIVITY 8.2

Use the 5E constructivist learning model to transact the concept '*Acids and bases when mixed, undergo neutralisation reaction*' or any topic of your choice. Design the activities under each stage of the model. You may give a power point presentation on this activity in the class to get critical observations of your classmates and the teacher-educator.

8.7 COLLABORATIVE LEARNING APPROACH (CLA)

One of the most important goal of education is to prepare learners for the world of work. Requirement for the world of work are exploring and developing one's own ability to:

- work collaboratively;
- communicating effectively and convincing others with one's own idea; and
- critical thinking and problem solving skills.

In the traditional way of teaching-learning, teacher passes on the information to learners, who passively listen, mechanically jot down the notes and vomit out the received information in the examination. In CLA, learners take responsibility of their own learning. It promotes self learning skills in them. They have to discuss their ideas with their group members, relating it to their previous experiences. Teacher facilitates situations for active participation in teaching-learning process by encouraging collaboration among the learners. She communicates the goal to be achieved within a limited time frame realising and respecting diverse needs of the learners and their different styles of learning. **Collaborative learning approach develops both academic and social skills in learner in an integrated manner.**

In the construction of knowledge, social aspect is also involved in the sense that knowledge needed for a complex task can reside in a group situation. In this context, collaborative learning provides room for negotiation of meaning, sharing of multiple views and changing the internal representation of ideas to the external reality. In the collaborative set-up, each learner individually and socially constructs meaning as she learns. Collaborative learning enhances motivation to learn and increases depth of understanding. In the group setting, learners develop a positive attitude towards the learning and materials on which they work on, as they contribute to it. Learning is more effective as students themselves take care to resolve any conflicting observation and opinion. It also gives them opportunity to apply the concepts in real-life situation and to learn to solve a problem through multiple ways. Disinterested students readily learn from their peers as their learning problems and issue are better appreciated by the peers.

Working in a group, students move beyond the caste, creed, region and get opportunity to develop friendship with each other. Students learn the qualities of doing collaborative and team work, patience, persistence of effort, completing the task within a set time frame, and sense of belongingness to the group as well as to their learning. They get to know who they are in the opinion of others and identify their own social and academic potential.

8.7.1 Steps of collaborative approach

- Problem, issue or concept is identified to be dealt within a group situation. It may be small or big, simple or complex, depending upon learning environment and teaching-learning process.
- Formation of groups (say 3 to 6 students) is facilitated by the teacher. Students are also facilitated to take up the task of their choice.
- There is exchange of ideas, discussion on the issue at hand or performance of activities or experiment to clarify the concept in group situation. Sharing of ideas facilitates visiting and revisiting the concepts.
- Teacher facilitates their interactions directed towards the set goal within stipulated time frame.
- Learning evidences are assessed throughout the teaching-learning process and feedback is provided to all groups of the learners.

After discussing the concept of *Addition and subtraction of vectors by graphical method and analytical method* in Class XI Physics, the teacher decided to solve following problem by collaborative learning approach.

Problem : Find the magnitude and direction of the resultant of two vectors A and B in terms of their magnitude and angle between them. (Fig. 8.2).

She invited one of the students to draw the figure on the blackboard and initiated solving the problem with the help of the class.

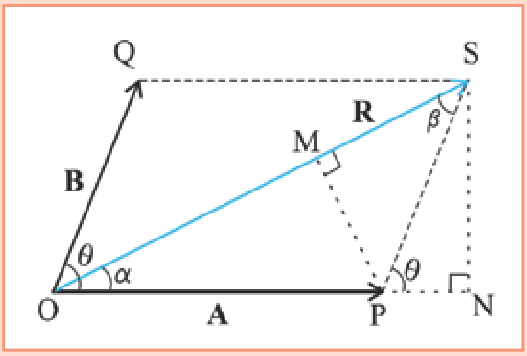


***Fig 8.2** Resultant of two vectors **A** and **B** in terms of their magnitude and angle between them*

Let OP and OQ represent two vectors **A** and **B** making an angle θ between them. Use parallelogram method of vector addition to get OS = **R** = **A** + **B** and geometry of the figure to get

$$OS^2 = ON^2 + SN^2$$

Applying trigonometry to find $\sin\theta$ and $\cos\theta$ and substituting values of ON and SN as $\mathbf{A} + \mathbf{B}\cos\theta$ and $\mathbf{B}\sin\theta$ respectively.
we get resultant vector

$$\mathbf{R} = \sqrt{\mathbf{A}^2 + \mathbf{B}^2 + 2\,\mathbf{AB}\cos\theta}$$

Direction of resultant can be given by

$$\sin\alpha = \frac{\mathbf{B}}{\mathbf{R}}\sin\theta$$

or

$$\tan\alpha = \frac{\text{SN}}{\text{OP+PN}} = \frac{\mathbf{B}\sin\theta}{\mathbf{A}+\mathbf{B}\cos\theta}$$

She facilitated the class to assemble in a group of four students to work on the problem and gave them 15 minutes time.
She observed that:

- Students started interacting with each other actively. One of the group members was writing the solution and all other members were justifying their points and steps to be written.
- Even shy students were not hesitating to ask questions or share their ideas in the group setting.
- Students learning with different paces were able to understand the concept applying trigonometry of $\sin\theta$ and $\cos\theta$ easily when explained by their peers and by sharing their idea.
- Individual understanding of almost all students was shared by each other in the groups, making their thinking explicit.
- It saved much of her time and energy, but not at the cost of learning of students. Group leader was selected by the group themselves and the teacher was facilitating the work of group through the group leader. Instead of checking the work of 32 students of the class, she corrected the work of 8 students only. These 8 students facilitated their group members to solve the problem correctly.
- It provided students an opportunity to develop interpersonal skills, such as team spirit, sharing of ideas, listening to others, respecting each other's ideas and problem-solving skills.
- It was easier to deal with the students having attitudinal problem in smaller group as they felt less threatened than in large classroom.
- Throughout the activity she kept moving around in the class, listening to their ideas and asking prompting questions to facilitate solving the problem.

8.7.2 Ensuring meaningful learning through CLA

- Ensure that the group is heterogeneous. There should be learners learning with different paces and styles in a group.

- However, keep grouping pattern flexible and consider the choice of learners also.
- Every time keep on changing the members of the group.
- Facilitate them to form group rule. If there is a disagreement, consensus should emerge.
- Make it a point that group leader will facilitate the work of the group and keep them organised. The leader should not dominate over other members.
- Tell one student of the class to pass on the name of group members and group leaders on a piece of paper for your record.
- While assessing, you may give same grade to all members of the group as far as possible. This will prompt the learner learning with greater pace to motivate other learners to perform.
- It will be convenient for you if you start this approach after 2–3 months the session starts. It will give you enough time to identify academic and social skills of all the students and help you to facilitate them in forming the group.
- Ensure that members of all groups should be made responsible for their work. All members should remain open to each other's idea and get equal opportunities to share their ideas and work (Fig 8.3).
- All members should be given liberty to express their ideas freely and work cohesively towards achieving the goal.

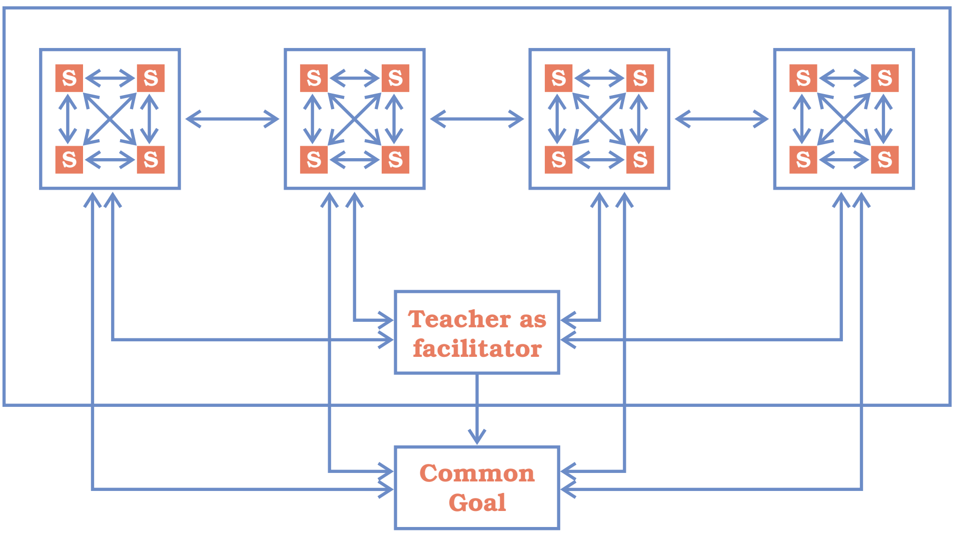


Fig 8.3 *A collaborative learning set up in classroom (S - student)*

Rohit, the teacher interacted with his class to formulate some rules for them when working collaboratively. The rules emerged after consensus of the class were as follows:

- Speak clearly and in complete sentence.
- Listen to each other's idea attentively without interruption.
- Be polite to others. Wait for your turn.
- Give value to each other's ideas.
- Evaluate each other' ideas and communicate it to the respective member.
- Member will try to improve without taking it otherwise.
- Follow the rule once framed by you. If you feel to bring any change, do with the consensus of all.
- If it is an activity or experiment to be performed in the group, everybody will get opportunity to try her hands-on it by turn.

8.7.3 Ways of applying collaborative learning approach

There are various ways in which collaborative learning approach may be applied such as given below.

(i) Brainstorming

- A problem is identified.
- Small groups are formed.
- All members are encouraged to find the solution and express their ideas.
- No idea is criticised. However, ideas can be modified.

Example: How can we minimise wastage of water?
Skills developed: Generating ideas, creativity.

(ii) Task group

- A task is identified.
- Small groups are formed.
- Each group of the class is assigned a specific task to be completed within a time frame.
- Task of each group is evaluated by other group.
- Completion of task is responsibility of all.

Example: Prepare models of lever of Classes I, II and III.
Skills developed: Taking responsibility, delegation of work, initiativeness, planning skills, accomplishment, evaluation and emotional skills.

(iii) Inquiry group

- Teacher creates a situation of some discrepant event during teaching-learning process.

- Students are helped to realise that there exists a problem, solution of which is to be inquired.
- Different groups work on the same problem and may come up with different hypothesis, solutions and conclusion.
- In order to get involved in the inquiry, learners may discuss, share their ideas, derive the equations, perform an activity, experiments and solve numericals.

Example: How would our life be affected if force of friction suddenly vanishes?

Skills developed: Problem solving skill, inquiry skills, analysis, synthesis and evaluation.

(iv) Tutorial group

- Teacher facilitates formation of group according to students' ability.
- A concept is identified by the teacher which can be learned in a group setting.
- A student having good understanding of the concept is identified as group leader by the teacher. Opportunity should be provided to various students in turn.
- The group leader is assigned the job of facilitating learning to all members of her group.
- The group leader asks questions with the members and encourages them to discuss their learning difficulties with her.

Example: Determine unknown resistance using a metre bridge.

Skills developed **:** Basic competencies related to a concept develop in all members.

There is a difference between cooperative learning and collaborative learning. In the former set-up, the centre of authority is the teacher, the group is held responsible for collective learning. However, the collaborative learning encourages self-governance, shouldering responsibilities according to one's interest and skill. Each member is accountable for the task. It is convenient to use former setting when a task can be done by one way only, e.g. learning formuale or writing or chemical equation as given in the textbook. Solving a problem, doing experiment/activity/project demands collaborative set-up.

8.7.4 Limitation of collaborative learning approach

- Teacher's dominance is reduced. The control is passed onto the students themselves. As a result, some teachers may feel like loosing control.
- If work of the groups is not properly monitored, misconception and naive concepts may breed in the thinking of learners.
- A few shy students may not participate actively in the group. Interaction of all members need to be continuously monitored.
- It may be difficult to check and recheck the work of all the groups working at one time for an inexperienced teacher.
- Very meticulous planning is required for meaningful learning to take place. Various aspects need to be considered— needs, interest and abilities of each student, scope of the activity/concept to be discussed in the group and classroom management, group dynamics of the class, etc.

ACTIVITY 8.3

Select any topic from the textbook that you plan to transact during your practice teaching. Discuss in a group of four members, how you will design teaching-learning experiences to transact the topic.

After about ten minutes discuss about your experiences of group work on the following lines:

- Did everybody get opportunity to share her idea?
- Do you feel sharing of ideas enriched planning of teaching-learning experiences?
- How is your overall experience about this collaborative work?

ACTIVITY 8.4

Form four groups in the class and work collaboratively to identify the cause of pollution of the river in or near your city. Perform this activity through the following approaches: (a) Brainstorming (b) Task group (c) Inquiry group (d) Tutorial group.

After performing this activity share your experiences and ideas with each other in the class.

8.8 PROBLEM SOLVING APPROACH (PSA)

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

Teacher facilitates them in identifying the problem. For this, she may create a situation, pose a question, perform activity or experiment, elicit inquiry from students to make students realise that a problem exists and help them to identify the problem. She sets up the stage for solving the problem. She helps them pose questions to initiate thinking, listens to their thinking, facilitate them to recall their existing knowledge and reconstruct them as and when it is required, and to use that knowledge to solve problems.

Some of the concrete examples of problem solving are given below:

- **Problems related to numerical ability**
  1. How much carbon dioxide can be obtained by combustion of 1.2kg each of carbon and oxygen?
  2. A rocket with a lift-off mass 20,000kg is blasted upwards with an initial acceleration of $5.0 ms^{-2}$. Calculate the initial thrust (force) of the blast.

- **Problems related to process development**
  1. Sodium iodide reacts with concentrated H_2SO_4 according to the following reaction :
  $$8NaI + 5H_2SO_4 \rightarrow 4Na_2SO_4 + 4H_2O + 4I_2 + H_2S$$
  How can you separate the released gases?
  2. Usually radicals of group III are identified in the alkaline buffer medium prepared by mixing NH_4CI and NH_4OH. Suggest an alternative of NH_4CI to design this buffer.
  3. You are given prisms made of crown glass and flint glass with different angles. Suggest:
     (a) a combination of prisms which will deviate a pencil of white light without much dispersion.
     (b) How a prism can disperse (and displace) a pencil of white light without much deviation.

- **Problem related to structures**
  Predict the bonding in NO_3 species.

- **Problems related to modification of alternative conceptions**
  1. Consider the change
  $$S(g) + 2e \rightarrow S^{2-}(g)$$

If sulphur $^{32}_{16}S$ is used as reactant here, then what is the number of electrons, protons and neutrons associated with S^{2-}?

2. Does the size of the image formed by a lens depend on its aperture?

- **Problem solving in daily life**

Problem solving skills related to physical science can be useful to solve problem of our daily life. Different types of problem may be related to the immediate environment, like *calculate change in gravitational potential energy of a mass of 50kg on taking it to a height of 20m*, may be modified as context specific with an idea *to work off a heavy dinner you ate on Saturday night, on Sunday morning you climbed a hill 20m high. Calculate change in your gravitational potential energy.* Many problems related to our environment, can be solved by encouraging inquiry and divergent thinking.

8.8.1 Steps in problem solving approach

- Students realise that problem exists. They conceive the situation as problem and provide rationale of the problem. They identify various issues related with problem and separate known and unknown things.

Students think, make decision—how, when and where, they can find the unknown issue by applying their existing knowledge and understanding who else can facilitate them in this process; what experiment/activity/calculation need to be done; what learning resources to be utilised.

- Students visualise the situation of the problem, process of the problem solving and expected solution of the problem. For this he may draw diagram/graph/flowchart/concept map.
- Students attempt to solve the problem. They make observation and collect data to explore the solution. In this process they apply their understanding to construct their knowledge.
- Students draw conclusion.
- Students present the record.
- Students generalise the conclusion.

Different problems may require different sequence of steps. Studies show that if same problem is presented to different groups of students in the class, they tackle the problem in different ways connecting their prior understanding.

8.8.2 Teacher's role in problem solving approach

Teachers' role in problem solving is to:

- facilitate students to define the problem;
- encourage students to plan their method of problem solving. Students learn by thinking themselves while working on problem and struggling to find the solution;
- ensure participation of all if problem is being solved in groups. Keep moving around the class and observing students' group work. Observe that all students are working on the task;
- encourage the group which has completed the task earliest to extend help to the group struggling with the problem, so that they can do it within the given time frame;
- call a few students to share their ideas on the problem when all the students have completed the work. They may use the blackboard or perform the critical part of the activity again to explain the phenomenon being studied;
- reflect and discuss explicitly on the problem, acknowledging contribution of students;
- collect the work of students. She may assess on the following parameters:
  - Reasoning and justification
  - Completion of work.
  - Correctness of solution.
  - Group participation
  - Novelty in approaching the problem.
  - Multiple approaches of solving problem

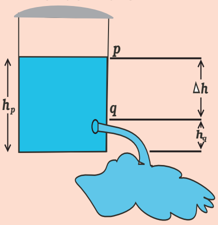
If a problem revolves around performance of an activity or experiment, then questions based on the activity may be designed as:

- What do you think would happen?
- Why will it happen?
- What did actually happen?
- Why did it happen?
- Do you find any difference from your prediction?
- How will you further explain your reasoning?

8.8.3 Problem solving approach: an example

Let us now see an example of how a teacher facilitated students to solve a problem based around an activity.

Table 8.1 An example of problem solving approach

What did the students do?	What did the teacher do?	Resources/Tools used by students	Steps for problem solving
Students observed that there was a hole in a large *can* slightly above the bottom. Stopper was filted in the hole and *can* was filled with water. As soon as stopper from the hole was removed, water started flowing from it.	When a discussion on the Bernoulli's equation was over, the teacher brought a large metal can to the classroom, She filled $\frac{3}{4}$ of the can with water.	• Observation and diagram of the situation  	• Realising that problem exists. • Drawing diagram.
Students' questions/ thinking aloud • I know Bernoulli's equation. Can I apply it here to find speed of water? Yes.	• Teacher asked "can we find speed of water flowing out from the hole?"	• Prior understanding about streamline flow and Bernoulli's equation.	• Defining the problem.
• Is the flow of water streamlined? Yes. • Streamline begins at the top of the water. Does it continue through the small hole ? Yes.	• Teacher told that student may use a meter scale for measurement. • She facilitated the class in forming three groups.		• Visualising problem.
• Since diameter of the hole at q is much smaller compared to diameter at the top of this *can*, can I neglect	• Teacher facilitated students to think about the problem. • She generated opportunity		• Analysing situation, identifying known thing.

What did the students do?	What did the teacher do?	Resources/Tools used by students	Steps for Problem solving
speed of water at p ? Yes.	to think and learn. • She scaffolded their thinking process. • She observed them working without giving any judgement right or wrong.		
• **Is volume flow rate of water constant i.e., Av = constant?** *Where A* is area of cross section of pipe, v is speed. Yes.	• She observed all students' work and helped them to think.	• Equation of continuity $Av = 0$	• Identifying unknown quantity.
• We have to find out $v_{q.}$ • Can I apply Bernoulli' s equation considering v_p = 0 ? Yes.	• She encouraged them to validate their reasoning and check their hypothesis.	• Understanding of Bernoulli's equation.	• Exploring the situation. • Applying previous understanding.
• Point p and q are both at atmospheric pressure. I think pressure at both points are equal.	• Helped them to break the problem into simple steps.		• Visualising the situation again by going back to the problem.
• From Bernoulli's equation P_1 + $\rho g h_1$ + ½ρ v_1^2	• She worked as facilitator.		• Putting the known things together to solve the problem.

What did the students do?	What did the teacher do?	Resources/Tools used by students	Steps for Problem solving
$= P_2 + \rho g h_2 + \frac{1}{2} \rho v_2^2$, *we have* $P_p + \rho g h_p + 0 = P_q + \rho g h_q + \frac{1}{2} \rho v_q^2$			
• *Here* $P_p = P_q = P_{atmosphere}$ *Therefore,* $P_{atmosphere} + \rho g h_p + 0 = P_{atmosphere} + \rho g h_q + \frac{1}{2} \rho v_q^2$ $v_q^2 = 2g\,(h_p - h_q)$ $= 2g\Delta h$	• Teacher asked, “can you find the speed of water at q by some other methods to check your result?”		
• What measurement to be taken?	• She initiated them to think over the problem again.	• Measuring scale	• Measuring
• Speed of water flowing from the hole is $v_q = \sqrt{2g\Delta h}$			
• Students measure Δh as 5 cm from the hole of the *can* and calculate $v_g = \sqrt{2 \times 9.8 \times 5 \times 10^{-2}}$			• Working with data
$v_q = \sqrt{0.48}\ \text{ms}^{-1}$			• Obtaining result
• Record their thinking process and present in the class.			• Recording
• Communicate with the class.			• Communicating

Teacher observed that another group of students came up with the idea that they could solve the same problem simply by using the concept of conservation of mechanical energy in the *earth water can system*. The group argued that in the given situation decrease in P.E. of water is $mg\,(h_p - h_q) = mg\Delta h$.

Since energy is conserved in an isolated system, decrease of potential energy corresponds to increase in kinetic energy (KE) of water. KE of water at the top may be neglected compared to KE of water flowing from hole at q. Therefore increase in KE = decrease in PE

i.e. $\frac{1}{2} m v_q^2 = mg\Delta h$

$$v_q^2 = \sqrt{2g\Delta h}$$

Teacher observed that one group of students was not active in solving the problem.

She enquired if they could define the problem and see that Bernoulli's equation can be applied here. She motivated them to work on the problem. She wanted to know their difficulty about solving the problem. The group wanted to perform the activity themselves to think about the problem. The teacher allowed them. This group came up with the solution a bit differently.

All the three groups presented their solution in the class. Each group tried to validate the result of each other.

Teacher obeserved that even a simple activity generated interest of the students about real world observations. Various questions related with the activity came up from the class.

- I have observed leakage of water from the overhead tank of my house in the similar situation. Can I find the speed of flowing water by using same relation, i.e. $v_q = \sqrt{2g\Delta h}$?
- If the hole q is slightly up or down, will the value of v_q remain same?
- If a similar hole is made at the bottom of the can, so that water flows simultaneously from both the holes, will their speed be equal?

How students learnt working on the problem

- While working on the problem, many questions emerged in the mind of the students. Solving the problem motivated them to answer their own questions and think about their own solutions.
- They observed the situation closely and applied their existing knowledge to solve the problem— explaining the observed facts. It led them to test the generalisation of their conclusion in novel situation and sparked interest in performing many new activities/experiment.
- Students observed the situation to realise that Bernoulli's equation exists not only in the textbooks, but also in our everyday life situations.
- They learnt not only the facts but also the method of discovering the fact that **Bernoulli's equation holds good in streamline flow of liquid.**

Bringing problems from everyday life experiences encourages students to observe their surrounding more critically. This leads them to develop process skills of science. Problem solving approach offers many possibilities for transforming classroom into active learning environment with a dynamic interplay of questioning, explaining, designing investigations, communicating ideas, collaborating and reflecting. Teachers' role is very important in facilitating students to formulate a feasible solution of the problem.

It is observed that teachers find it difficult to step out from their comfort zone of traditional chalk and talk method. After students have learnt the concepts required to solve a problem, they should be trusted to work on the problem. If proper activities and learning environment are planned in a workable and feasible manner, this approach can promote critical and divergent thinking in learners.

ACTIVITY 8.5

Madhur is a student of Class VIII. His eyes start watering when he passes through a busy road-crossing near the school. He feels suffocated around that particular area. He describes this problem to you. How would you facilitate him to discuss the issues related with the cause, effects and possible remedies of air pollution in order to help him identify the problem and find its solution? Think-pair-share your ideas with your classmates.

8.9 CONCEPT MAPPING

Concept maps are graphical tools for organising and representing knowledge about certain concepts. A concept map represents an understanding of the relationship and hierarchy between important set of concepts. They promote meaningful learning in science. This can be understood by studying the following components of a concept map.

(i) **Concept:** Concept may be thought of as a mental framework of an event or an object. Any event or object is a concept because it has some identifiable properties or ideas associated with it. In addition, a concept also has a label (name).

For example – A 'ball-point pen' is a concept because it has certain properties, i.e., it is long; it has a refill and it is used for writing. Also it has this label 'ball-point pen.'

In a concept map, concepts are usually presented enclosed within a circle or a box. The first step is to identify and enlist various key concepts in the topic. These concepts are then arranged in a two dimensional array hierarchically in descending order, i.e. the more general concepts are placed at the top followed by the less inclusive concepts. Concepts occurring at same level of observation are placed at the same horizontal level.

For example – For transacting the topic *Structure of atom*, the arrangement of the concepts can look like the one given in Fig. 8.4 (a), (b).

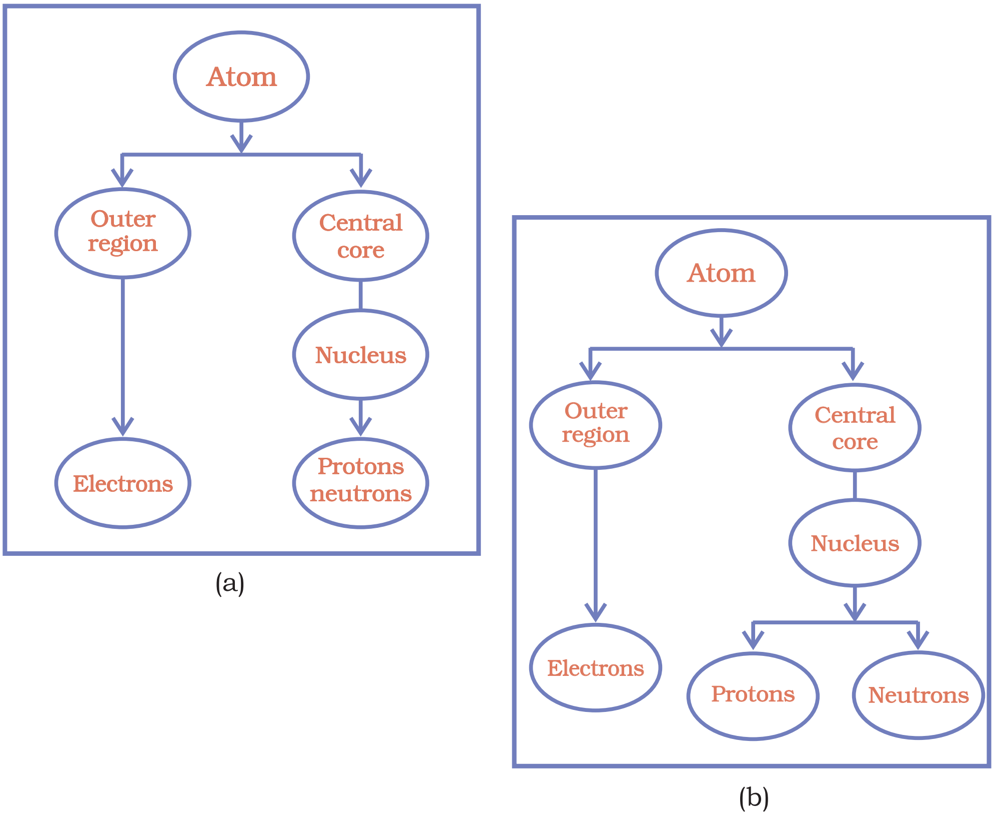


***Fig. 8.4** (a), (b) Formation of concept map in process*

(ii) **Linkages:** They are usually represented by arrows or lines. They link two concepts appropriately.

(iii) **Labels for linkages:** The label for most linkages is a word/s or a phrase— although sometimes we use symbols such as +, –, x or ÷ for linkages in mathematics. Labels highlight the relationship between two concepts (Fig. 8.5). **These labels for linkages are also named as proposition.** Two or more concepts can be cross linked, if significant relationship exists between them.

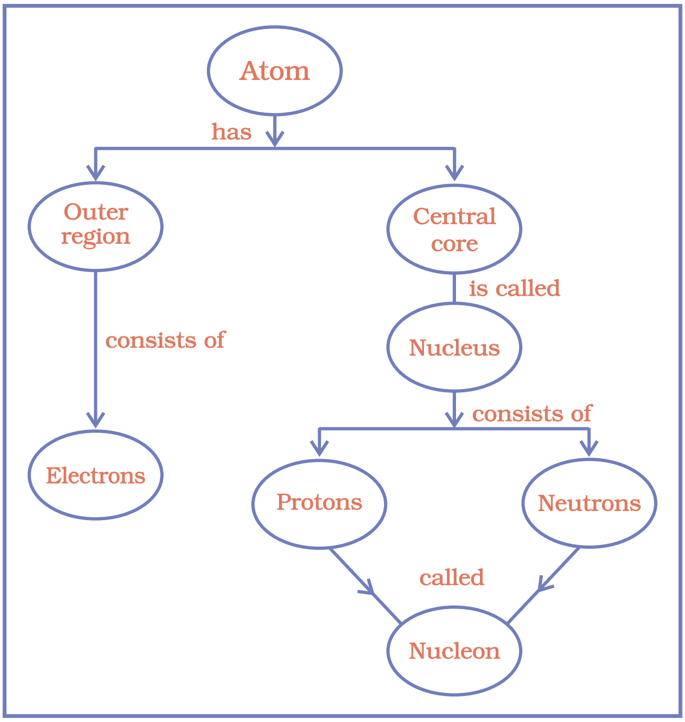


Fig. 8.5 *A concept map*

Thus, we observe that concepts in a concept map are not isolated collection of the concepts. They are interconnected together through well labelled linkages. Cross-links are particularly powerful connections, which form a 'web' of relevant and interrelated concepts. These links enhance the anchorage and stability in the cognitive structure of concepts rather than just connecting general concepts to specific concepts. They tend to connect different subconceptual structure. There is no limit on the number of connecting lines. As a matter of fact greater number of connecting lines represents integrative thinking and depth of knowledge of the learner.

Concept mapping (as developed in its standard form by Novak in 1984) is considered to be an offshoot of the Ausubelian approach. Novak himself asserts: "My work and the work of my students on concept mapping has been based upon Ausubel's theory of meaningful learning (1963, 1968). It is this fundamental principle that has led our research group to search for better ways to represent what the learner already knows."

Ausubel's Theory of Meaningful Learning

David P. Ausubel made an attempt to improve the effectiveness of the conventional lecture method used in the teaching-learning process. He propounded the theory of meaningful verbal learning. The theory of meaningful learning is concerned with three aspects of the teaching-learning process: (1) how knowledge (curriculum content) is organised (2) how the mind works to process the new ideas (learning) and (3) how these ideas about curriculum and learning can be applied by teachers when they present new teaching–learning material to students. Ausubel (1963) believed that a parallel exists between the way subject matter is organised and the way people organise knowledge in their minds (cognitive structure). He emphasised that every academic discipline has a structure of concepts (and/or propositions) that are organised hierarchically. In other words, it can be said that at the top of each discipline are a number of very broad concepts that include or subsume the inclusive concepts at the lower stages of organisation. The level of abstraction of concepts increases as one proceeds in the reverse order (bottom to top). Thus, we may imagine a discipline as being composed of a pyramid of concepts, all linked together, with the most concrete concepts at the bottom and the most abstract concepts at the top.

8.9.1 Phases of the concept mapping

Phase I: Presentation of abstraction

- Students are presented with a definition or generalisation, which is linked to their existing cognitive structure.
- Students are asked to identify various concepts and sub-concepts and enlist them.
- Students' understanding of these concepts is assessed by asking them to provide new and unique examples.

Phase II: Propositional phase

- The teacher uses prompts and cues to guide the learners to arrange the concepts hierarchically with the broader/general concepts at the top and the less inclusive concepts at the bottom, giving the whole structure the look of a pyramid.
- The various concepts are interlinked logically by using (arrowhead) lines.
- These lines are supplemented by word/words/phrases, which define them and illustrate meaningful relationships between the various concepts.
- The whole concept map is viewed as a network of concepts.

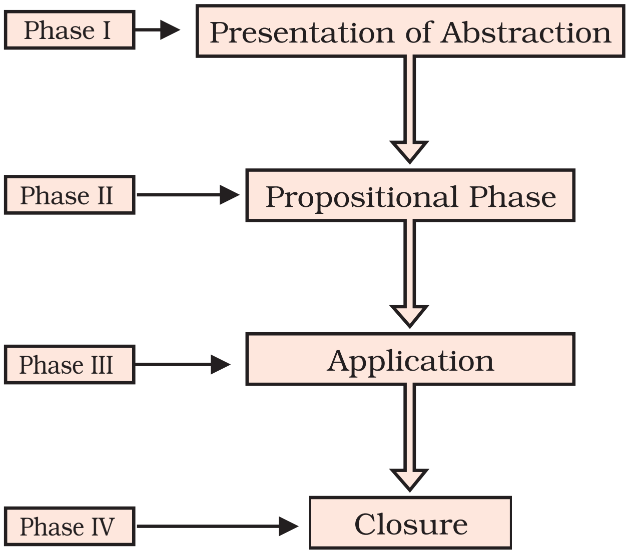


Fig. 8.6 *Phases of Concept Mapping*

Phase III : Application

The learners apply their knowledge to generate new examples and reflect on the existing ones.

Phase IV : Closure

The learners summarise the major ideas evolved during discussion (Fig. 8.6).

8.9.2 Uses of concept maps

The potential of concept maps needs to be explored in our schools as they are of tremendous use for learners, teacher, curriculum developers and evaluators. Some of the uses of concept maps are highlighted here.

(i) **For learners:** Concept maps can be used by learners for meaningful acquisition of concepts. This can be accomplished through various mechanisms, such as:

- Providing a visual representation of a particular material (e.g. text material). This helps the students to make better sense of the material, specially when the material is complex. A conceptual framework can be provided to elaborate on the key concepts.
- Helping learners develop new relationships among concepts in one or more related areas, thereby creating new meaning.

- Summarising material when preparing for examinations.
- Motivating learners to think and engage in active learning as they try to construct the most plausible relationships.
- Helping learners identify gaps in their knowledge.
- Making learners aware of the explicit roles that language plays in the exchange of information.
- Promoting reflective thinking associated with pushing and pulling of concepts, putting them together and separating them again.
- Allowing learners to exchange view, thereby achieving shared meaning, which is possible, because concept maps are explicit.
- Analysing an activity and an experiment in terms of procedure or content and reduce subsequent burden on working memory.
- Providing practice by using specific concept labels which act as attention catchers especially for students struggling to learn.
- A study (Prabha, 2005) shows that concept mapping as a teaching-learning strategy can be applied to facilitate learners to draw the ray diagrams of the formation of images by the lens and mirrors for different position of the object. It provides a holistic view of the phenomena of reflection and refraction of light.

(ii) **For teachers**: Concept maps may serve teachers in several ways such as:

- Helping in planning a lesson by identifying key concepts, their prerequisites and relevant examples.
- Serving as a means for providing an overview of some unit.
- Providing an operational definition of a teaching-learning goal by indicating the learning objectives that are to be attained.
- Serving as a remarkably effective tool for helping learners to identify their alternative framework (misconceptions and naive concepts).
- Helping in planning interdisciplinary teaching-learning by developing a conceptually coherent programme that integrates concepts from different areas.

Thus, Construction of concept maps may be provided as an activity prior to a lesson to reveal previous knowledge of the learners; as homework; for consolidation; to summarise and review the lesson; in a group discussion; as an individual assignment in evaluation, etc.

(iii) **Concept maps as effective tools in complex laboratory environment**: The connection between theoretical concepts and experimental observations can be considered as criteria for meaningful learning of scientific concepts in complex laboratory environment. New experiments can be designed to understand integration and linkages with the theoretical part of the concepts using concept maps. Concept maps can also be created as a part of post-laboratory activity.

ACTIVITY 8.6

(i) Develop a concept map on any one topic each taken from secondary and higher secondary stage textbooks. Share and discuss your work with your friends.

(ii) How will you use the above concept map to identify – (a) Gaps in the knowledge of the student on this topic (b) Misconceptions and naive concepts on the topic.

8.10 EXPERIENTIAL LEARNING

Ashok is a student of class VIII. He had studied about fermentation process in his class. He was told that the bread he eats has acquired porosity, because of fermentation process. He wanted to see the making of bread to understand this process. He visited a nearby bakery with his parents. After observing the process of bread making, he discussed the various steps with the bakery owner. This made his learning of the process of fermentation explicit. This type of learning is experiential learning.

Experiential learning is the process of learning from direct experiences. However, experiential learning is not just a fieldwork or connected with learning from real-life situations. **It is a theory that defines the cognitive process of learning, emphasising the importance of developing four kinds of abilities, viz. concrete experience, reflective observation, abstract conceptualisation and active experimentation where a learner encounters some experiences.** These four stages are suggested by Kolb & Fry (1975) and follow each other as depicted in Fig. 8.7.

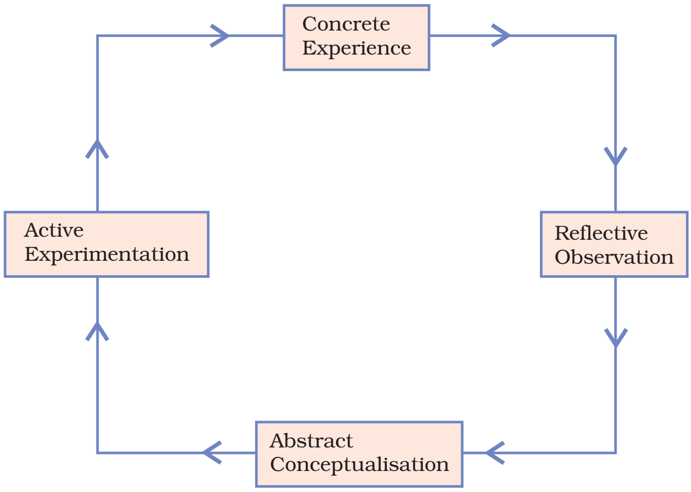


Fig. 8.7 *Four stages in experiential learning*

Concrete experience is followed by reflection on that experience on a personal basis. This may then be followed by the derivation of general rules describing the experience, or the application of known theories to it (abstract conceptualisation), and hence to the construction of ways of modifying the next occurrence of the experience (active experimentation), leading in turn to the next concrete experience. All this may happen in a flash, or over days, weeks or months, depending on the topic. This complete process allows one to learn new skills, new attitudes or even entirely new ways of thinking.

ACTIVITY 8.7

In order to let your learners know more about the process of pasteurisation of milk, you have organised an educational visit of your learners to a pasteurisation unit. Following are the experiences and cognitive processes which the learners undergo at the pasteurisation unit. Classify these experiences into the four stages of experiential learning and fill in the Table 8.2.

- The students see big silos (containers for keeping/storing milk) being cleaned and sterilised.
- They see the process of milk being tested for adulterants.
- They see the process of pasteurisation being done.
- The students can themselves test milk for adulteration.
- They can take away a small kit to detect adulteration of milk at home.
- They ask questions related to packing and marketing of milk.

- They conceptualise the process of pasteurisation.
- They see how flavoured milk is being prepared.
- They taste the various types of flavoured milk available there.
- They see a documentary on pasteurisation.
- They learn that the milk should be heated to 720^0 C for killing the germs.
- They come back and share their experiences with other students.

Table 8.2 Four stages of experiential learning

Concrete experiences	**Reflective observation**	**Abstract conceptualisation**	**Active experiment**
The students observe silos	---------	---------	---------
---------	---------	---------	---------
---------	---------	---------	---------

8.10.1 Abilities of an experiential learner

Based on the four stages of his model, Kolb argues that effective learning necessitates the possession of four different abilities on the part of the learner as shown in Fig. 8.8.

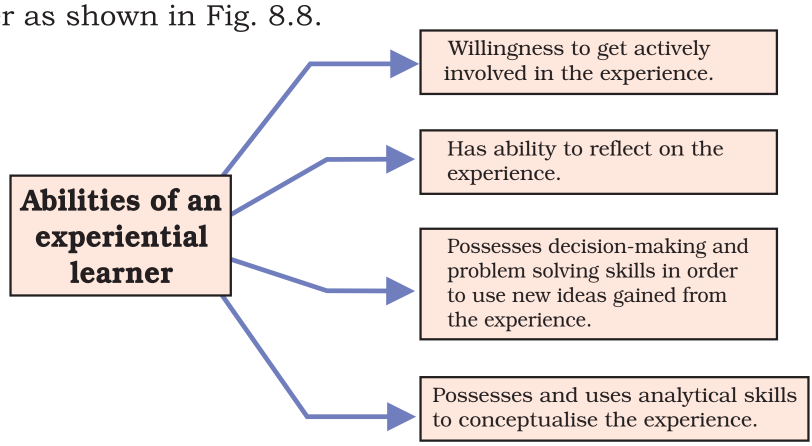


Fig. 8.8 Abilities of an experiential learner

The experiential learning can take place in formal education also. One will have to develop proper strategy of planning activities and involving learners. An example in the formal system of teaching- learning can be the use of science park. In a science park students can play with various models and exhibits and learn the basic principles involved in them. In some cases, the learners can be engaged in survey work, conducting interviews of the scientists, collecting different chemicals and materials for activities, writing assignments, etc.

8.10.2 Role of a facilitator

The process of experiential learning depends on creating experiences where learning can be facilitated. An excellent facilitator believes in the creed: "You teach *some* by what you say, teach *more* by what you do, but most of all, you teach *most* by who you are." And while it is the learner's experience that is most important to the learning process, it is also important not to forget the wealth of experiences, a good facilitator also brings to the situation. An effective experiential facilitator is one who is passionate about his or her work and is able to immerse learners totally in the learning situation, allowing them to gain new knowledge from their peers and the learning environment created. The facilitator stimulates the imagination, keeping learners hooked to the experiences.

ACTIVITY 8.8

You have to deal with the concept of 'compost formation' as part of your science club activity for the learners of your school. Design a set of activities under the four stages of experiential learning that will impart meaningful learning to your students. Give a presentation in the class to get a critical review of your work.

8.11 COGNITIVE CONFLICT

Sarthak, a student of Class VI was observing the sky. He observed that the sun rises in the east and moves towards west as the day proceeds. However, he learnt in his science class that the sun is fixed and the earth revolves around it. He was puzzled. Sarthak could not decide, what is the actual fact. He had a strong belief that the sun moves as he observes it everyday and the teacher has provided just the opposite fact.

The learner generates her own conception about how the natural world works. An inappropriate generalisation can become very strong in the mind of the learner and then difficult to change. The personal conception is very much valid in learner's framework and this can be her alternative conception (misconception or naive concepts). The occurrence of alternative conception which are significantly different from scientific conception give rise to cognitive conflict. Cognitive conflict has a long tradition as a strategy for promoting conceptual change in science learning. We have already discussed on **Catch, Challenge and Change** of naive concepts in section 5.3.1.

Conceptual Change

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

(i) **Identical fit:** The new information/concept/experience may exactly fit the existing one (schema). This means that the learner is able to make sense of new information on the basis of existing knowledge which may not be scientifically correct.

(ii) **Approximate fit:** The new information may form an approximate fit with an existing idea. These learners encounter new ideas, but do not give up old ideas. The learners belonging to this category assimilate the new ideas, but cannot accommodate. They do not reach the situation where cognitive conflict can occur.

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

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

8.11.1 Generating cognitive conflict

Cognitive conflict may occur due to the following situations:

(i) Encounter with discrepant events: On encountering a new concept/ event the learner may try to explain it with the alternative concept that she has developed and may arrive at a solution that is different from what actually happens. Such an event is called a 'discrepant event'. Thus a cognitive conflict is between a learner's cognitive structure related to certain physical reality and actual physical reality.

If a glass full of water is taken and the learner is asked that what would happen if we put a brass ball or bob of the simple pendulum in it, the student may reply that water will overflow. If one asks the reason for such answer she may say, 'no two bodies can occupy the same space simultaneously.' This is already in her congnitive structure. Now if one takes one glass full of water and drop few pins (say 10) one by one and asks the student to observe, the student will observe no overflow of water. This will create a cognitive conflict with her conviction that water will overflow from the glass after dropping pins.

(ii) Encounter with mutually conflicting alternative conceptions

This situation arises when the learner faces a situation where she can explain the same event using two different already existing cognitive structures which are at conflict with each other.

A duster is on the table is at rest. The student has two alternative concept to explain the situation.

- One alternative concept from Newton's Law of motion that no force is acting on a body at rest.
- Another concept that all bodies (duster also) on the earth are acted upon by the force of gravity.

If one tries to seek answer to the problem using the above two previous knowledge, she would arrive at a cognitive conflict.

(iii) Occurrence of identical conflict: Learners may frame different alternative concepts from the same concept. When learners are allowed to discuss about a concept, then there is a possibility that conflict may occur between learner's different concepts that she has generated.

Problem: A simple pendulum is oscillating as shown in the Fig. 8.9. The bob oscillates from A to B then to C. Suppose the thread breaks when the bob reachs position B. Draw the path the bob would take to reach the floor.

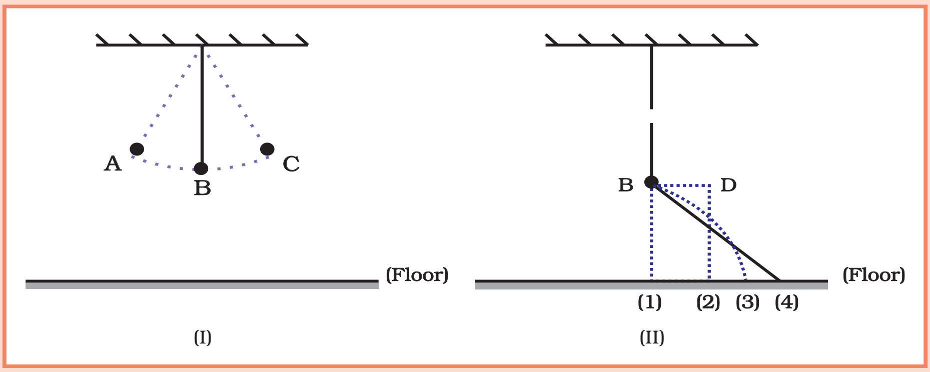


Fig. 8.9 *(I, II) Path of the bob of a simple pendulum*

When the above situation was created, students made different predictions.
Prediction I: Like a freely falling object, it will fall vertically downward at position (1) in Fig. 8.9(II).
Prediction II: Due to inertia, the bob will move for sometime along its original path, then it will fall vertically downward at position (2) in Fig. 8.9(II).
Prediction III: The bob will describe the path of a parabola and fall at position (3) in Fig. 8.9(II).
Prediction IV: The bob will describe the path as shown at position (4) in Fig. 8.9(II).
The students are allowed to argue among themselves to arrive at the conclusion with scientific reasoning.

8.11.2 Techniques to generate cognitive conflict

Some of the techniques are:

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

Vikas, a secondary school teacher conducted following study in Class X before starting teaching-learning of the topic *Electricity*. Students were given a problem where a bulb, a piece of wire and a cell were supplied to each one (Fig. 8.10). They were asked to connect them, so that bulb could glow. The students were asked not to cut the wire.

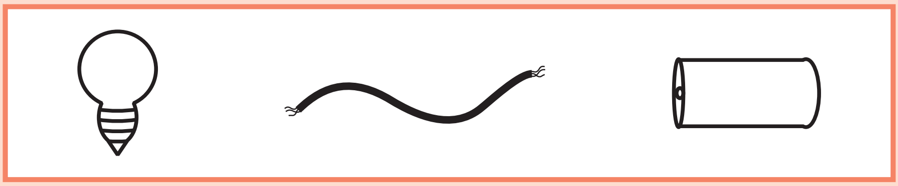


Fig. 8.10 *A bulb, a piece of wire and a cell*

The students were familiar with the concept of a closed circuit. However, only ten percent of the students could connect it correctly [Fig 8.11 (a)]. The remaining students connected in the ways shown in Fig 8.11 (b) (c) and (d) respectively.

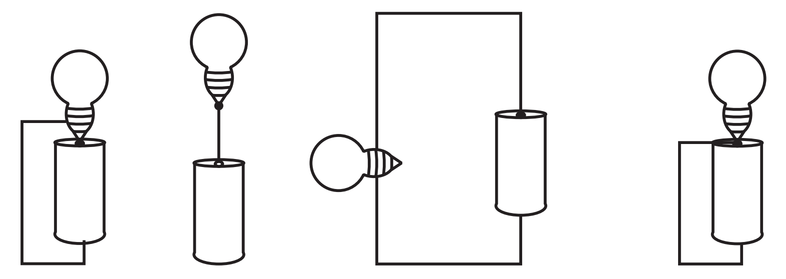


Fig 8.11 *(a), (b), (c), (d) Different electric circuits setup by students using a cell and a bulb*

Vikas facilitated students to observe themselves whether using situations (b),(c) and (d), the bulb glows. The students who made connections as shown in Fig (b) had the model of a torch light or flash light. Those who connected as given in (c) and (d) had the conception that electric current will pass through the bulb by just touching. The students were allowed to discuss and resolve the conflict between their models and their observations. They observed that the bulb glows when it is connected with the cell as shown in Fig. 8.11 (a) as it provides a closed path for the current to flow.

After performing the activity and having discussion with them, they came to know that they were not correct which gave rise to dissatisfaction with their existing models. This cognitive dissonance stimulated the transformation of their existing knowledge about a closed electric circuit into the new knowledge or reconstruction of knowledge.

8.12 INQUIRY APPROACH

Discussion on metals and non-metals in Class VIII was going on. One of the students raised the question, "What is the meaning of non-metals?" Ramprakash the teacher facilitated the students to collect different small objects like nail, coal piece, chalk, pen, pencil, eraser, spoon, key ring, paper weight, metallic and plastic lunch box, handkerchief, etc. available in the class. He helped them to observe that different objects were made up of different materials. Students made a list of different materials from which the objects were made.

Students articulated their observation that the spoon is made up of steel and eraser is made up of rubber. As rubber and steel are different materials, they should belong to different categories. Ramprakash overheard the students talking, 'rubber is soft' 'steel is hard' and 'I can break the rubber, but cannot break the iron nail easily.'

Ramprakash facilitated the class to form five groups. He helped them to find out the different physical properties of objects, like which objects produce ringing sound when struck hard (sonorous), which materials can become a thin sheet by beating (malleability), which materials (aluminium) can be drawn into wire (ductility), which materials can conduct electricity (electrical conductivity) and which materials shine (lustre). Objects and materials like hammer, cells, connecting, wires, etc. were made available to them to test their physical properties. Students recorded their observations in a tabular form.

Table 8.3 Physical properties of different objects/materials.

Objects/ materials	**Change in shape/ flattens/ break into pieces**	**Good conductor/ poor conductor of electricity**	**Produce ringing sound or not**	**Shiny /dull**	**Can be drawn into wire or not**
1. Iron nail (without rust) 2. ______ 3. ______ 4. ______ 5. ______ 6. ______ 7. ______ 8. ______ 9. ______ 10. ______	Flattens	Good conductor	Produce ringing sound when struck with an object made up of iron.	Shiny	Can be drawn into wire.

Ramprakash did not tell them which are metals and which are non-metals. He facilitated the students to segregate the materials that produce ringing sound; can be drawn into wire; can be beaten into sheets; have lustre and then to record their observation in **Table 8.4** under the category metals; and the materials not having the above physical properties under the category non-metal. He helped them to classify the materials as metals and non-metals by asking questions.

Table 8.4 Metals and non-metals

Objects	**Material**	**Metal**	**Non-metal**
Nail	Iron	✓	—
Eraser	Rubber	—	✓
…………			

In the above teaching-learning approach you find that teacher does not give lecture on the types of materials/classification of materials on the basis of their properties. He created the situation in the class to make them observe, think, classify, record, conclude and communicate about the classification of materials on the basis of their physical properties.

Thus, an inquiry-based teaching-learning approach promotes exploration of ideas, experimentation and critical thinking. The inquiry should relate the real life experiences of the students to their learning process.

Inquiry approach is not just about asking and answering questions. Learners should be facilitated to engage themselves in using equipments and measuring devices to collect data and pose questions for explanation; using graphs and diagrams for communication and getting clarification of ideas from multiple sources. Inquiry begins with observation and can be carried out through reasoning, hypothesis, experimentation and activities and communicating ideas effectively to construct argument and generate knowledge.

ACTIVITY 8.9

(i) Design activities based on the inquiry approach to facilitate learning of the concept on 'rusting of iron' for Class VII students.

(ii) Do you think that there can be various ways to involve students in inquiry? Discuss in the class on this aspect of science learning.

8.13 ANALOGY STRATEGY

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

Teaching With Analogies (TWA) model as given in includes the following six steps (Glynn, 1995):

(i) Introduce the target concept;
(ii) Review the analogue concept;
(iii) Identify relevant features of the target and analogue;
(iv) Map similarities;
(v) Indicate where analogy breaks down; and
(vi) Draw conclusions.

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

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

Analogue	**Target**
Solar System (familiar ideas)	Rutherford Model of Atom (scientific knowledge)
(i) Sun	(i) Nucleus
(ii) Planets	(ii) Electrons
(iii) Sun and planets attract each other	(iii) Nucleus and electrons attract each other
(iv) Sun has more mass than all planets.	(iv) Nucleus is very heavy as compared to electrons.

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

ACTIVITY 8.10

Illustrate the different stages of Glynn strategy to introduce the concept of Rutherford atomic model by analogising it to the solar system.

8.14 FACILITATING LEARNERS FOR SELF-STUDY

Facilitating self-study is different from assignment method of teaching-learning or teaching study skill or giving homework. Facilitating self-study is learner-centred and it facilitates them learning to learn and become independent learner.

Generally homework is given as backward looking work, i.e. whatever is discussed in the class, learners do them again or solve textbook exercises to develop certain skills. Facilitating self-study can be done as a forward looking work which motivates the learners to learn about the concept further and develop self-confidence in them that they themselves can learn.

Self-study does not mean reading textbooks, memorising facts, vocabulary and formulae and making notes. When the learner understands science deeply, she sees the interconnections among various ideas related with the main concepts. In this process, her previous ideas are challenged and she constructs new knowledge from her experience. For meaningful learning to take place, it is important for the learner to consider following questions— What do I know? How do I know the concepts that I know? What is the relationship of this new concept with my previous ideas on this concept? How can I apply this learning in real life situation?

By designing motivating learning situations, teacher can empower learners to take responsibilities of their own learning and become motivated and independent learner. Some teachers find the syllabus at higher secondary stage too heavy and textbooks too voluminous which is difficult to cover within stipulated period of time. Many times teachers feel stressed and hard pressed for time to 'cover the syllabus.' With proper planning teacher can let the learners be in-charge of their own learning. Teacher needs to develop trust on learners' capabilities and instill the confidence in them that they can learn many things themselves. If textbook is analysed carefully, a teacher can observe that application part of many concepts can be given as assignment for self study to students. Following steps may be followed to facilitate and monitor self-study.

- Identify the concepts or application of concepts which you feel students can learn themselves. Teacher may think on the following lines to identify the concept.
    - Do students know the basic concepts required to solve a problem or derive an equation or solve a numerical or perform the activity/experiment? What do they know?
    - Have they studied about this concept in previous classes or in other subjects (e.g. they study about *atoms*, *nuclei*, *dual nature of matter* in their chemistry class).
    - Have you facilitated them to perform activity/experiment on the concept and involved them in discussion, so that you are confident that students understand the concept?

- You may facilitate students to learn to draw concept maps/ flow charts/graphs/pictorial representation of the concept.
- You may help them to select/choose the steps to be followed for the study. You may provide
  - name and page number of the reference book/textbook, list of relevant and reviewed websites for the concerned concept.
  - brief description of the activity/experiment that needs to be performed.
  - diagram to be drawn.
  - time frame in which the activity is to be completed.

Identification of the concept: Derive thin lens formula.

What do they know: Students have the following previous knowledge which can be applied to derive thin lens formula.

(i) Relation between object and image distance in terms of refractive index of the medium and the radius of curvature of the curved spherical surface, i.e.,

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Where v = image distance

u = object distance

n_2 and n_1 = refractive indices of two media.

R = Radius of curvature.

(ii) Tracing the paths of rays in convex and concave lenses using the laws of refraction and finding how rays are refracted and images are formed at different positions for different position of the object.

(iii) Performing activity using a convex and concave lens and three sources of light (laser torches) as is obvious from the Fig. 8.12 (a) and (b).

(iv) Students understand that they may choose two rays to find the image of an object by a lens.

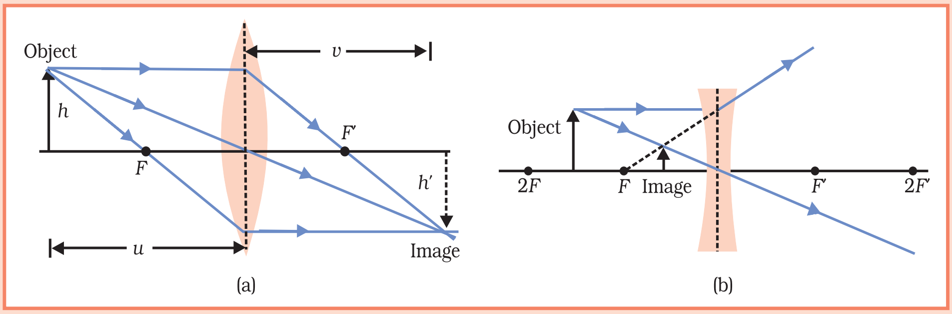


Fig. 8.12 *(a), (b) Tracing rays through (a) convex lens (b) concave lens*

- A ray emanating from the object parallel to the principal axis of the lens after refraction passes through the second principal focus F' (in a convex lens) or appears to diverge (in a concave lens) from the first principal focus F.
- A ray of light passing through the optical centre of the lens emerges without any deviation after refraction.
- A ray of light passing through the first principal focus (for a convex lens) or appearing to meet at it (for a concave lens) emerges parallel to the principal axis after refraction.

Figs. 8.12 (a) and (b) illustrate the rules for tracing rays through a concave and a convex lens. You may prepare sheet for guiding them to do the study. Flexibility should be provided on the mode of working. Providing Self -Study Sheet (SSS) would ensure that all students do the work.

How do they know — Discussed in the class.

Self-Study Sheet (SSS)

What to do: Derive thin lens formula.

How to do:

- Draw ray diagrams for the position of an object and the image formed by a double convex lens depicting refraction at the first spherical surface as well as the refraction at the second spherical surface.
- While drawing the ray diagram recall the activity performed in the class which showed refraction of light rays through lenses.

Time frame: One day.

Mode of Presentation of Work: In the notebook/on a chart paper/power point presentation.

Important: Write in your own words.

Every student may do the work differently.

Fig. 8.13 shows a student's way of learning derivation of thin lens formula. This is one of the ways to learn derivation of the formula. Some students may use other representation to show networking of the concepts.

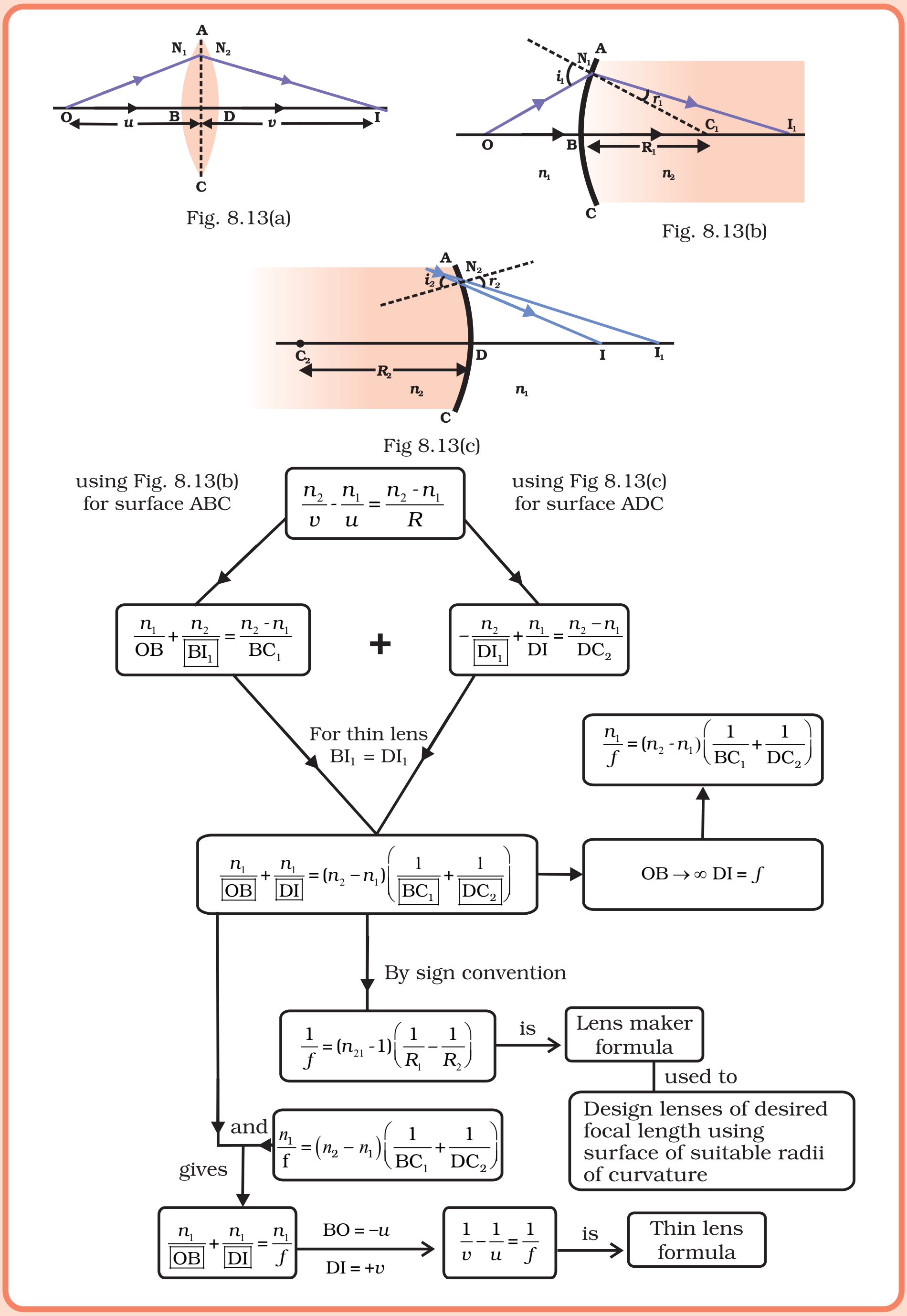


Fig. 8.13 *A student's way of learning derivation of thin lens formula*

Learning product as well as process of learning should be assessed in this strategy. Teacher can talk about the thinking process learners use to analyse and work to accomplish the task. Facilitating self-study encourages learners to take charge of their own learning. However, teacher should be well aware of prior learning needs of the learner. She can take the role of a co-learner with her and facilitate her to locate various resources of learning. A critical discussion on the concerned concept can be carried out as a follow-up action by the teacher. Liberty can be given to the learners on what, when, how and where the learning task can be accomplished. Considerable planning is required on the part of teacher for this task. Part of the lesson/unit to be learnt by self-study may be mentioned in the unit plan.

ACTIVITY 8.11

Prepare a Self-Study Sheet (SSS) for learners to transact any concept in physical science at higher secondary stage. Share and discuss your work with your friends.

8.15 COMMUNICATION IN SCIENCE

Class XI students prepared a four act play on *Electricity* and presented it in the morning assembly of the school. The play was written by the students themselves with a little guidance from the teacher. In the process of writing the play, the students searched many reference books and internet and interacted with senior citizens to collect the required facts. The first act showed the scene during nineteenth century, the hardship people faced without electricity. The second scene was set up in early twentieth century when electricity was invented. Not many electrical and electronics gadgets and devices had emerged by then for the comfort of the life. The third scene showed later part of the twentieth century. The fourth act depicted the comfort and convenience of life with a number of electric and electronic gadgets of modern days . A girl was commenting on the scenes from the background. The act ended with her speculation about more comfortable life in twenty second century.

Planning of some extended curricular activities related to science provides a learning platform to students. Students should be encouraged to plan and to express themselves through acting and drama. As the planning of the act is done, students get opportunity to propose their ideas, enter into discussion, prepare scripts, make preparation— the experiences they get here are not affordable in a regular classroom teaching-learning. If properly planned, presenting drama and acts on science topics/concepts can be equivalent to regular classroom teaching-learning. Teacher can help students to distribute the work among all of them and involve them equitably.

8.15.1 Qualities of an effective science communicator

A science teacher needs to have good communication skills for effective teaching-learning of science. To have good science communication skills it is essential that the communicator

- uses the language which the students can understand and feel comfortable with;
- should understand well whatever she wants to communicate;
- should believe in two way interactive communication, which means that she not only talks to the class, but also listens to them;
- should know her students well and be sensitive towards their needs and concerns;
- should pay heed to the students feedback and make use to it in designing her communication content;
- should always check for accuracy and correctness of facts/figures before making use of the same in the presentation; and
- should choose the occasion, time and place for communication with care to suit the students.

Communication in science is a very objective process. For effective transaction of curriculum, communication needs to satisfy the following criteria:

- Communication should be simple and easy to understand. Whatever medium (oral or written) is used for communication, it should be according to the age level of the learners. The learners should be able to relate to what is being communicated.
- Communication should arouse interest of the learners and make them receptive to learn. This will motivate the learners to participate in the learning process.
- Communication should enrich existing knowledge of the learners. In fact, effective two-way communication can identify gaps in the learners' knowledge as well as find there alternative concepts. Further, communication can help them to restructure their concepts on the basis of scientific explanation.
- Communication can be used to relate and connect various concepts and impart holistic and functional knowledge to the learners which they can use for problem solving effectively.

8.15.2 Developing communication skills in learners

Teaching-learning is a two-way process. Good communication skills of science need to be developed in learners also. The whole task of communication cannot be left to language teacher alone. In fact, each teacher needs to be a good communicator herself and encourage her learners to express their thoughts and ideas effectively. For this, various modes of communication can be used so as to enable the learners to choose the communication channel which they find appropriate according to their needs and abilities. Some of these are described here.

A. Communication by oral expression

(i) Debate: To begin with, debate can be initiated on simple topics for the learners in the class. The teacher can act as a monitor and facilitate the learners to express their views explicitly on the topic they have chosen. Gradually bigger platforms like school stage, inter-school competitions, etc.can further improve their communication skills and instill confidence in the learner.

(ii) Discussion: During classroom interactions, the teacher should encourage the learners to say what they feel about a particular topic. For example, while teaching *Acids, Bases and Salts'* to upper primary students, the teacher can initiate a discussion by asking the questions like:

- What are the acidic substances used in our home?
- How do you know these are acids?
- Can all acids be tested ?
- How are acids different from bases?, etc.

Positive reinforcement provided by the teacher as well as use of appropriate clues and prompts can help the learners to discuss freely and arrive at valid conclusions.

(iii) Group presentations: By using collaborative learning approach, learners should be motivated to communicate their ideas and develop the ability of effective group presentation using figures, graphs, observation table, summary of result of experiments, etc. The presenter in front of an audience should have good social skills besides having good coordination skills among the group members. These short oral report presentations in a group can be supplemented by visual materials made by the learners themselves for conveying their ideas and focusing the audience's attention at desired points.

(iv) Science plays and school assembly programmes: Science skits and plays may be planned on various topics such as:

- Using paper and jute bags instead of polythene bags.
- Reducing garbage production.
- Recycling plastics and its uses.
- Alternate sources of energy.
- Energy crisis and
- Pollution of a river by human activities.

This would help in creating awareness and sensitise the learners about various scientific and social issues. Morning assembly can be a very crucial platform for staging of such plays and skits wherein the whole school can be involved.

B. Communication by written expression

(i) Writing for school magazines: Students should be encouraged to write about science news/discoveries/related matter for the school magazine. The article should be scientifically correct and should be presented with lucid language and proper figure, graphs and pictures in an interesting manner.

(ii) Encouraging writing in the classroom on regular basis: The teacher should encourage students to write to express their opinion on the topics like— *applications of science in everyday life, separating mixture into components, need of classification of elements, why do we fall ill, global warming,* *etc.* during teaching-learning process. After writing, students can be asked to share their views in the class.

(iii) Poster making/Slogan writing: These are creative expressions of one's feelings and can be an effective way of communication.

Besides these activities many inter-class, inter-house, inter-school competitions can be organised to develop communication skills of learners. Science clubs can take up many such activities to promote communication in science. We shall further study about science club in Chapter 13 *Lifelong Learning in Physical Science.*

Science vocabulary

Vocabulary in science has special meaning. A scientific vocabulary is not science in itself. It is a tool with which science is communicated. Words like *distillation*, *thermodynamics*, *radioactive* have very precise meaning in science. Sometimes a word has different meanings in science and in common languages like 'potential', 'work', etc. Science teacher is concerned in making the learners aware with scientific meaning of the words. However, introducing them with too many words makes them feel that science is difficult— it is a jargon of difficult words. Sometimes they use the scientific word in wrong sense like *force* instead of *pressure*, *atoms* instead of *nucleus*.

Science teacher has to draw attention of students to specific words in order to facilitate them to understand the meaning. This can be done by:

- associating the word with their previous experiences;
- providing first-hand experience with the meaning of the word;
- using digital/electronic media; and
- using diagram, models, encyclopedia, pictures, etc.

Maria, the teacher had to introduce the concept of *diffraction* to students. She asked them to recall their observations regarding a patch of dark cloud obstructing sunlight in the sky. The bright light around the cloud or the silver line as it is often called is due to diffraction of light. She drew attention of the students to the fact that we can hear sound around the corners of a building or a wall due to diffraction of sound. Then she showed them the multicoloured patterns seen in a compact disc (CD) which is also due to diffraction of light. From such examples students could develop their primary concepts of diffraction. Later she helped them to observe a diffraction pattern formed by filament of a bulb when viewed through two razor blades (taking necessary precautions) adjusted to form a narrow single slit. She explained that diffraction occurs due to spreading of waves from a slit whose width is very small compared to wavelengh of light.

Note how the teacher cited past experiences to give meaning to the word diffraction**.** It helped students to fix association of the term diffraction with a phenomena. Next two classes were conducted on the same concept (diffraction due to a single slit and solving problems based on diffraction). The word diffraction was used frequently. Students could get the meaning of the word in broader sense by performing the activity and solving the problems. To introduce some abstract concept, sometimes an elaborate process is necessary.

ACTIVITY 8.12

Prepare and present a talk of 5 minutes on *green energy* in the class.

ACTIVITY 8.13

Present a dance programme showing structure of some molecules like H_2O and CH_4.

ACTIVITY 8.14

Discuss, prepare and present a skit on the *transmission of heat through solid, liquid and gases.*

Project 8.1

Create and maintain a blog on your ideas about various approaches of teaching-learning of physical science.

Project 8.2

Discuss with your classmates and make a plan for a school science magazine, seeking their contribution towards various articles. Submit the manuscript of the magazine to your teacher educator.

8.16 SUMMARY

A teacher should have knowledge and understanding of various approaches and strategies of teaching-learning so that she has a choice to select the most suitable one according to the needs of the learners. This way, she can take maximum advantage of whatever learning situation arises during transaction of concepts. However,

approaches and strategies discussed above are not exhaustive. A science teacher has much flexibility to devise a strategy, select and switch over from one strategy to other as per the requirements of the teaching-learning situation. She can involve learners also to bring flexibility in the transaction of concepts, rather than follow step by step process of an approach and strategy. The most important characteristics of learner-centred classroom is to adjust and mould the teaching-learning approaches and strategies according to need of the situations, as the thought patterns of learners that would progress and direction of conversation in the class that would take place, cannot be foretold.

Many teachers often explore new ways of transacting the curriculum in addressing the needs of learners within their specific classroom context (including constraints of space, large numbers of students, compulsion of examination, etc.) These efforts are often pragmatic, creative and ingenuous. However, these efforts remain invisible to the school and the larger teaching community, and are usually not valued by teachers themselves. These innovative and creative ways of teaching-learning needs to be encouraged and supported by the system, so that they can become a body of practice.The sharing of teaching-learning experiences and the diverse classroom practices can provide opportunities for an academic discourse to develop within schools as teachers interact with each other. This will also encourage to generate and apply new ideas facilitating innovation and experimentation.

You cannot teach a man anything, you can only help him find it within himself.
— Galileo Galilei (1564-1642) Italian physicist and astronomer.

EXERCISE

8.1 Discuss the historical background of the development of various theories and approaches of learning since 1950s. How would you justify the need to change these theories and approaches?

8.2 'All children are capable and eager to learn.' Keeping this in mind what factors will you consider in deciding and using approaches and strategies of teaching-learning of a particular concept of physical science?

8.3 Why does a teacher need to know various approaches and strategies of teaching-learning of physical science? What factors will you consider in selecting an appropriate approach for transacting a concept? Discuss the features of constructivist approach with examples.

8.4 Explain Collaborative Learning Approach (CLA) in detail highlighting its features. How can you incorporate this approach in various learning situations? Illustrate with examples.

8.5 Suppose you were to transact the topic *Reactivity series of metals* to Class X students. Which approach would you find suitable to be followed in the class. Justify your answer.

8.6 How will you use problem solving approach to transact the concept *Atmospheric pressure* in class VIII? Identify the various issues and activities that you will deal with each step of the problem solving approach.

8.7 Explain with an example how can concept mapping be used to identify

(a) gaps in the learners knowledge;

(b) naive concepts of the learner.

8.8 Discuss how can you use concept map in your teaching-learning process for various purposes. Illustrate with examples.

8.9 Suppose you needed to facilitate learning on the topic *Use of indicators to test acids and bases* to Class VII students and *Magnetic effect of electric current* to Class X students. Which of the approaches— inquiry or problem solving would you find more appropriate to transact this topic? Justify your answer using suitable activities that you plan to undertake in the chosen approach.

8.10 Explain cognitive conflict and analogical strategies of teaching-learning taking examples of some concepts of physical science.

8.11 Suppose you are the incharge of the science club in your school. Enlist the activities that you will organise as part of science club activities to develop communication skills of the students.

8.12 It is often seen that students who are spoon fed readymade knowledge by teachers and parents at primary and upper primary stages, do not fare well in academics at senior levels. In the light of this statement justify the importance of (i) constructing knowledge on their own, (ii) self-learning of the students.

8.13 You have to organise a science exhibition in your school. Make a concept map of the tasks you have to undertake for this work? How can concept map assist you to systematise your work by helping you to remember what you have to do and when? Do you think concept maps could be used in daily life to solve problems? Reflect on these aspects of concept map.

8.14 A teacher after transacting the concept of *living and non-living beings,* asked the students whether 'fire' is living or non-living. One of the students argued and put forth her view saying, *fire is living.* The student had her own way of framing the concept as

- fire can move from place to place;
- fire can create fire;
- fire needs oxygen (without oxygen there can be no fire);
- fire needs food in the form of dry wood, leaves, paper, etc. for its survival; and
- fire responds to stimulus {when one strikes at fire flashes come out).

So, fire is living being.

After knowing the student's way of making meaning, what innovative teaching-learning strategies can the teacher adopt for constructing the knowledge of the student?

Chapter 9

Community Resources and Laboratory

9.1 INTRODUCTION

The pluralistic and diverse nature of Indian society definitely makes a strong case for preparing not only a variety of textbooks, but also other materials which children can use, enjoy and learn. Teacher with her experience and planning may use many learning materials for designing effective learning experiences in transaction of concepts applying various approaches and strategies. Students feel a sense of ownership to their learning when it is related to their own experiences. Moreover, a stimulated environment of learning physical science demands many resources of learning. All these materials may not be available in the school. In such a situation the teacher may have to fall back upon resources available in the community. There are a number of community resources that can be used for facilitating the learners in the construction of knowledge of physical science and to find the relevance and meaningfulness of this knowledge in the context of the world beyond the four walls of the classroom. The community resources can be physical or human. These resources can be utilised in two ways—either community can be brought to the class or class can be taken to the community. In fact, teachers, students, administrators and community can collaboratively work to utilise various community resources. In this chapter we shall discuss about learning resources in learners' immediate environment and the resources that could be used with the help of the community. In the latter part of the chapter we shall also discuss on the improvisation of apparatus, science kit and laboratory as learning resources.

Providing learners with learning experiences in relevant situations beyond the four walls of the classroom can give them idea of the context of the concept being transacted along with a sense of environmental and cultural appreciation. It can be an organised field visit or just stepping out of the classroom. Urban schools can have access to science centre, museum, national laboratories, etc. Whether the school is located in urban or rural area, it can utilise the physical surroundings and its immediate environment as learning resource to further students' interest in science. **Integrating classroom learning with learners' own experiences outside the classroom contextualise their learning.** This promotes learners' creativity, participation and interest in science classroom, which help them to shift away from the rote memorisation and have a feel of science.

Limited resources and geography should not be a barrier to meaningful learning of physical science. Information and Communication Technology (ICT) has made it possible for us to contact a person from any corner of the world. Work of the specialist working in various sectors, such as health, transportation, communication, computer technology, machines, art, music, industry, etc. are related to scientific aspects. Their expertise can be utilised for the enrichment of teaching-learning experiences. For this, the teacher would need to have information and idea of the available resources, and the person who is to be contacted. She can take the help of students also to identify the local resources. Using community resources has added advantage of strengthening linkages between the schools and the community. The teachers' ability to plan learners' experiences in a manner that permits imaginative use of such resources directly affects the quality of education schools.

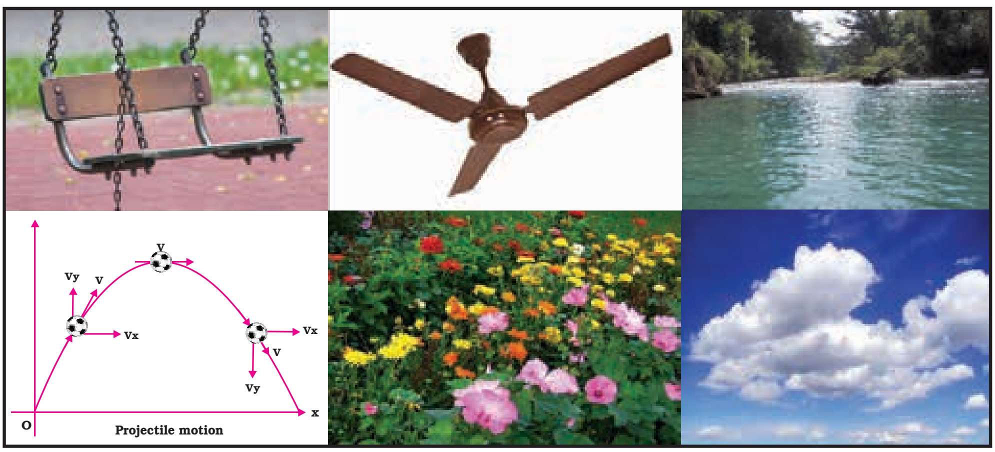
9.2 LEARNING RESOURCES FROM IMMEDIATE ENVIRONMENT

Immediate environment of the learner is a natural learning resource that can be used in making curricular choices. The immediate environment includes physical, natural and socio-cultural world. Learners find acquired knowledge significant if learning of science takes place from the primary context of their immediate environment.

Process of constructing knowledge is a continuous one, which goes even outside the school. It implies that learning is also a continuous process and it has a broader meaning than what takes place in school. Teachers of physical science should appreciate that the environment around the student is full of learning opportunities. They might utilise every conceivable situation for learning process. For example, on the school ground certain things are almost always available such as soil, plants, trees, insects, birds, sunshine and shadows, bicycles and automobiles. A range of activities can be organised from these things, situations and materials. Students can measure difference in the temperature in the Sun and the shade using a laboratory thermometer to observe that the Sun is a source of energy. They may repeat this activity at the same time and the same place for a week(s) to analyse the data and learn to plot graph from their own data. The effect of projection angles on the range of a projectile can be shown with a stream of water from a garden hose. A corner of the room may be used to organise learning materials, to keep some appropriate reference and other self-learning materials collected by the students (sample of soils, fabric, magnetic toys, etc.). When some students finish their assigned lesson before the pre-arranged time, they may pick up something from the corner to occupy themselves.

In fact many learning opportunities are available in the school ground/classroom/kitchen/bathroom/markets/on the roads itself. Outside the classroom, experiences of the learners can be used in teaching-learning of science to provide them first-hand experience for enhanced learning and a sense of appreciation to the environment. It may consist of a wide range of materials. Some examples from the immediate environment and the concepts that can be explained using these examples are given below:

- **Bicycle tyres:** Friction, gears, levers.
- **Cemented surface/paved surface/grass:** Friction, heat absorption.
- **Slide:** Gravity, friction.
- **Swing:** Oscillatory motion.
- **Merry go round:** Centripetal and centrifugal force.
- **Flagpole:** Change in size and position of shadow.
- **Football/cricket/hockey:** Projectile motion, rate of change of momentum.
- **Electric fan:** Conversion of electric energy into mechanical energy, rotatory motion.
- **Pool/pond/river:** Buoyancy, Archimedes Principle, Ecosystem.
- **Watching the stars:** Constellation.
- **Rainbow:** Refraction, total internal reflection of light.
- **Clouds:** Water cycle, light travels faster than sound, lightning, thunder.
- **Seasons:** Tilt of earth.
- **Garden flower:** Colours (electromagnetic spectrum).
- **Common Salt:** Solubility, concentration, etc.
- **Sunlight:** Heat, temperature.
- **Phases of moon:** Luminous and non-luminous bodies, revolution of the moon around the earth.
- **Day and Night:** Rotation of earth.



Immediate environment of the learner is a natural resource of learning

Abida, a science teacher wanted to transact the concept to her students that flowers have a number of coloured pigments. She took the students to the school lawn and asked them to observe the brightly coloured flowers and discussed with them that colour of flowers was not a single colour but a combination of colours. But her students were not convinced. With their help, she prepared a flower extract. In the classroom, she demonstrated the chromatographic separation of coloured pigments from the flower extract. This encouraged students to carry out the same activity themselves using different flowers and observe that each flower extract actually contained more than one colour.

Now let us look at concepts and the examples of materials or events from the immediate environment to illustrate those concepts.

- **Pulleys:** Washing machines, generators, etc.
- **Projectiles:** Long jump of athletes, water fountain, fireworks, trajectory of a football, basket ball, golf ball, etc.
- **Lenses and mirrors:** Camera, sunglasses, contact lens, barber's mirrors, driver's side mirror, bathroom mirror, etc.
- **Fibres:** Jute, wool, cotton.
- **Conversion of one form of energy into another:** Almost all machines around us.
- **Propagation of waves in solids, liquids and gases:** Propagation of longitudinal and transverse waves in slinky (a type of big spring), ripples in water reservoir, echo in a big hall/well, etc.
- **Some natural pH indicators** that can be used in teaching-learning situations are given below.
  - **Beets:** Basic solution will change the colour of beet juice from red to purple.
  - **Onion:** It can be used as olfactory indicator. We cannot smell onions strongly in basic solutions. Also red onion changes from pale red in an acidic solution to green in a basic solution.
  - **Turmeric:** It contains a yellow pigment, curcumin, which changes from yellow at pH 7.4 to red at pH 8.6.
  - **Colour change lipstick:** Test the colour change lipstick to determine its pH range. Most cosmetics change colour due to changes in pH.
  - **Red cabbage pH indicator colours:** Take filter paper (or coffee filter) and soak it in a concentrated red cabbage juice solution. After a few hours, remove the paper and allow it to dry. Cut the filter into strips and use them to test the pH of various solutions.

pH	0	2	4	6	8	10	12
Colour	red	light pink	dark pink	purple	blue	blue-green	greenish yellow

ACTIVITY 9.1

Take a round of your institute/college with your classmates and identify some of the things and places you can use or utilise in teaching-learning of physical science at upper primary/secondary/higher secondary stage.

ACTIVITY 9.2

Use a slinky to produce transverse and longitudinal waves and discuss how you would use it to transact various concepts of waves during teaching-learning of physics at secondary and higher secondary stages.

I am a teacher facilitating learning of science to Class X students. While developing the concepts on *Acid, Bases and Salts,* I used some natural indicators other than those usually available in the laboratory.

- I took a tablespoon of turmeric powder and added a little water to make a paste of it. I helped students to make turmeric paper by depositing turmeric paste on blotting paper/filter paper, letting it dry and then cutting it into strips.
- I also used cabbage leaves, coloured petals of some flowers, such as Hydrangea, Petunia, Heranium as natural indicators.

I facilitated students to perform various activities by using these natural indicators. However, there were a couple of students who were visually impaired. I had observed these students having the same talent as students with normal eyesight. I felt that these students should not be deprived from attending the practical classes in science, especially in chemistry.

To create an inclusive environment in the class, where all students could learn together, I performed some activities by using substances with their odour depending on their acidic or basic nature, i.e. olfactory indicators. I facilitated students with special educational needs to distinguish acids with the bases. Other students in the class helped these students to explain the process involved in the test.

–Experience of a teacher

Learners should be encouraged to construct and reconstruct their knowledge from observing, classifying, categorising, questioning, reasoning, arguing, and interacting with the natural world and people around them. A science teacher should think on the line of flexibility, contextuality and plurality in designing curricular experiences.

In order to relate teaching-learning of physical science with immediate environment of the learners, a number of carry home activities can be identified as an extension of classroom activity. Many such activities can be suggested, such as:

- list some of the changes taking place around you (physical/chemical);
- list acids, bases and salts commonly used in our daily life;
- locate, observe and note down examples of the lever/machines, pulleys, gears used in our daily life;
- list things at home which are good or bad conductors of heat and electricity;
- make measurements (length, volume, area) of some solids and liquids.

ACTIVITY 9.3

Examine any textbook of science at upper primary/secondary stage. Discuss in a group and make a list of activities that can be performed by observing keenly and using materials available in the immediate environment. These activities can also be considered as carry-home activities for the students. Share your list with other groups.

9.3 USING COMMUNITY RESOURCES

Community resources can be used in teaching-learning of science either by bringing community to the class or by taking class to the community (Fig. 9.1).

Fig. 9.1 *Using community resources*

9.3.1 Bringing community to the class

Teacher must explore opportunities for active engagement of the parents and the community in the teaching-learning process of physical science. Different members of the community also hold a large variety of valuable knowledge. Many of these members may be willing to share their knowledge and experience with the students. These members can be invited to school and learners can interact with them. Teacher should remain aware of the range of community, individuals and organisations that can be accessed to provide significant learning experiences to learners. Learners can visit their places of work also. The expertise of members varies from community to community. Some examples are:

- **Electrician:** Domestic wiring, short circuit, fuse, switches, elements of iron, toaster, etc.
- **Carpenter:** Lever, inclined plane, wedge, torque, etc.
- **Musicians:** Depending on the kind of instrument they play (string, membrane, air column) they can talk about how sound changes by changing various parameters (length, thickness). If possible they can bring few types of instruments and demonstrate them to the class.
- **Veterinary doctors:** How to measure body temperatures of different animals, features of various living beings which help them to adopt to their specific surroundings.
- **Potters:** Rotational motion, centripetal force, etc.

9.3.2 Taking class to the community: field visit

In many cases learners can be taken to the community resources of learning. When organised from the point of view of enrichment of teaching-learning experiences, it is a field visit. This makes learning realistic, concrete and interesting. Learners get opportunity to discover the concept and their connection with their environment. They can use this opportunity to learn various skills in interacting with the physical world, materials, technology and other people. It helps students to create knowledge by figuring out the components of objects, events, people, and concept. Let us now see the various advantages of field visits in teaching-learning of science.

Advantages of the field visits

The field visit:

- helps in providing first-hand experience to the students which is not possible within the four walls of the classroom;
- enriches general knowledge of students. It supplements the classroom learning;
- helps in broadening the outlook, deepens insight and widens vision of students;
- gives the students new ideas and vision for taking up projects;
- helps to deepen understanding of the concepts and brings clarity in the subject. It also helps in concretising the abstract ideas;
- helps the students develop an inquiry attitude towards the environment;
- develops skills in science processes like observation, collection, classification and analysis of data;
- brings the awareness that science is all around us and not just in books;
- relates the community to the learners, teachers and school and encourages sharing of responsibility of child's learning with the community;
- Acknowledges the authenticity of community knowledge, etc.

Organisation of the field visits

Planning: The entire planning can be done by students under the guidance of a teacher.

First a guide sheet can be prepared. It should have learning details, physical details and administrative details.

Learning details: Consist of sites to be visited, data to be collected, list of questions to be asked to the persons working at the site and any process which is to be studied, etc.

Physical details: Route to be taken, time schedule, personal equipments, provisions for refreshments, meals, first aid box, materials to be carried such as umbrella, camera, etc.

Administrative details: Teacher needs to give details, purpose and outcome of the trip for getting permission from the administration of the school for the field trip.

The checklist of a planned field trip can be

- objective of the field trip;
- date of the field trip;
- time of departure;

- date and time of return;
- name of the supervisors accompanying students;
- rules of conduct for students;
- materials students need to bring for the trip, such as water bottle, umbrella, field diary, etc;
- cost for the trip; and
- permission from parents.

Transport facility should be also planned in advance.

Prior to students field visit, the place to be visited should be seen by the teacher and a student representative. They should find out, whether learning objectives would be achieved or not. The main aim of the visit should be providing learning experiences; pleasure should be the secondary aim. The objective of the visit should be clear to all learners in order to optimise learning.

Teacher should plan follow-up activities in order to make learning experience, a fruitful one. After coming back from the field visit students can discuss their observations and experiences, ask questions and share photographs. Teacher needs to encourage students to submit the report and mention explicitly what they learned from the visit. Evaluation of the field visit can be done in the light of the planned objectives. It has been discussed in detail in Chapter 11 [Section 11.4(C).3].

The resources maintained by the community can provide great learning experiences for students. These resources if tapped properly can help us in moving from science as an interpretation of visual and auditory symbols (words) to science as an experience. These community resources vary from place to place. Some such resources are listed below:

- Hydroelectric/thermal power plants.
- Science Museums: Actual objects, working models, mirrors, lenses, etc.
- Planetariums: Solar systems, telescopes, night sky watching.
- Jantar Mantar: Sun dials.
- National Physical Laboratory: Standard of time
- Movie theatre: Acoustics.
- Hospital: Mirrors used for examining ear, nose, throat, teeth, ultrasound.
- Optician: Lenses used in reading glasses, grinding and coating of lenses.
- Market:
  - ➲ Shoe shop – soles of sport shoes, friction.
  - ➲ Fabric Shop– Fibre obtained from plants (cotton, jute), fibre

obtained from animals (wool), fibre obtained from insects (silk).

- ➲ Things like paints (solution), gem stones (solid solutions), jellies (gel), foam rubber (solid solution) as examples of colloidal solution.

- Electroplating unit– How objects are electroplated, How waste material is discarded considering environmental issues?
- Construction site– How lightning conductor is fixed in a building?
- Barber shop– Images in parallel mirrors.
- Fire brigade
- Railway station
- Post office
- Police interceptor vehicles– measuring speed of moving vehicles.
- Bakery
- Chemical industry
- Hillside– erosion effects.
- Beaches– wave actions.
- Junkyard – electromagnetic crane.

ACTIVITY 9.4

Analyse a textbook of science/physics/chemistry to make a list on the topics on which members of the community may be invited to the class to share their knowledge for the enrichment of teaching-learning experiences. Your friend may do this activity on some other class textbook and you can share your ideas with your classmates.

ACTIVITY 9.5

Plan a field trip for your students of Class VI to XII to any place of scientific interest with various details on learning and physical and administrative matter.

ACTIVITY 9.6

Plan a field trip to a place of educational value along with all student-teachers of your class and the teacher-educator.

9.4 POOLING OF LEARNING RESOURCES

In the school the classroom is the first physical space that a child associates herself with and feels closest to. Thus, the first pooling of resources can start right from the classroom itself. This pooling of resources can be developed in the form of a science corner. The development of science corner becomes even more important in schools situated in areas of resource crunch where setting up of full science laboratories is difficult. For this, one or two tables can be arranged in the classroom. Children should be encouraged to bring materials they think are relevant for discussions and display. These materials can be used to provide them hands-on experience. Also these materials should be continuously updated and changed as per the learning needs, interest and curiosity of children.

Systematic experimentation as a tool to discover or verify theoretical principles is an important part of curriculum at secondary and higher secondary stage. Thus, schools require well equipped laboratories for students at this stage. Yet these are still not available on a scale required for effective teaching-learning of science. As a part of an effort to provide all children with necessary hands-on experience of equipment and experiments given in their science curriculum, at least at cluster level, a resource centre may serve as cluster laboratory. Schools of the cluster could plan their timetable so that for half a day, once a week, their science laboratory class is held at the cluster level laboratory.

Specific equipments such as telescope could be shared among schools if they are placed at the cluster centre, which can then serve as a resource centre. For the period of teaching-learning on the concerned concept, the teacher can borrow materials from the centre and thereafter, return them to enable other teachers to borrow them. In fact teaching aids and other learning materials or models selected in the science exhibition can also be placed at the cluster centre. In this way, the resources gathered by one teacher can also be utilised by others, and it would become possible to have multiple sets necessary for the whole class to use. Neighbouring schools, colleges or training colleges, institutions may allow students to work in their laboratories. Teachers need to be resourceful to utilise such opportunities.

There is a growing emphasis on Information and Communication Technology (ICT) for effective learning. Many schools are now equipped with computers, and in some areas radio and TV based learning and interaction are being introduced. Some selected schools may also have teleconferencing facilities. These Information and Communication Technology (ICT) facilities can also be shared between schools.

In many parts of the country, community libraries are functioning in rural areas, and government libraries exist in many district headquarters. A network of school libraries with cluster level/block level library can be established for its enrichment.

Pooling of various learning resources can be a part of the overall curricular plan of the school to enhance participation of various schools and agencies.

ACTIVITY 9.7

Visit a nearby school and observe how does the teacher of physical science pool different learning resources. Interact with the teacher to discuss how various other learning resources can be explored and pooled for the enrichment of teaching-learning experiences of physical science.

9.5 IMPROVISATION OF APPARATUS

Many schools are not well equipped and face financial constraints in buying materials and equipments for carrying out activities, demonstrations and experimentation due to availability of limited funds. But this does not mean that there is no way out. An enterprising teacher can critically look at local resources and find possibilities of carrying out innovative activities for teaching- learning of science using local, low cost, easily accessible materials. She can encourage and help students in making improvised apparatus. With a bit of creativity and imagination, a teacher with the help of students can convert day-to-day usable articles, household wastes or discarded materials and materials collected from immediate environment into valuable learning resources. Such learning resources, while being interesting and effective, do not result in financial burden on school. This is, however, possible when the experiment is of qualitative nature and does not require too much precision.

Students can also be involved in collecting locally available materials and improvising apparatus. This will enthuse the children to explore new things. It will provide them an opportunity of creativity, self-expression and self-development. They will be able to connect learning of science to their environment. In the long run, it would help to inculcate scientific temper in them.

The learning resources from the immediate environment can be used at all stages of school education. At primary and upper primary stage of school education, almost all science activities and demonstrations can be done using resources from immediate environment. At secondary and higher secondary stage, many activities, demonstrations and some experiments also can be performed in physical science by using such improvised apparatus. Let us see some examples.

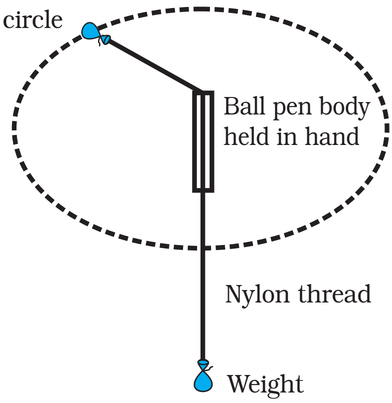


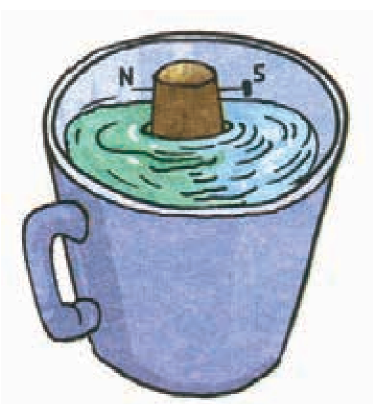
***Fig. 9.2** An activity displaying centripetal force*

1. Centripetal Force: Take the body of a ball pen, Through this, slip a strong string of about 50 cm to 100 cm length. Tie packets of sand on the two sides of the string as shown in Fig. 9.2. Hold the pen body along with the string vertically in your hand. Now start whirling it with your hand. The packet of sand at the top starts rotating and the string starts moving up. Try with different-sized sand packets and with different speeds. What makes the lower packet move up? What is the effect of changing the speed and why? This simple improvisation would help you learn about the force that comes into play when objects undergo rotational motion.

2. Surface Tension: Take a metallic U-clip. Place it on a small piece of newspaper. Fill a cup full of water. Carefully put this newspaper along with the U-clip horizontally on the water surface, so that the U-clip does not get wet. If kept undisturbed for a few minutes, we observe that the newspaper absorbs water and sinks while the U-clip keeps floating on water. Discuss why does it keep floating. Why does the U-clip sink if disturbed?

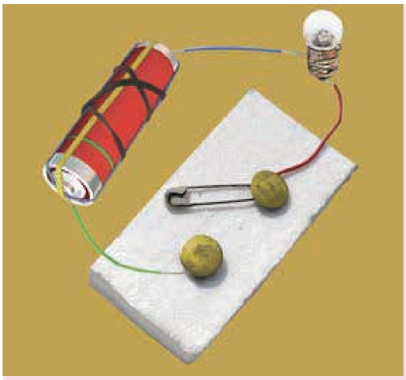
U-clip floating on water

3. Magnetic Compass: Magnetise an iron needle using a bar magnet. Now, insert the magnetised needle through a small piece of cork or foam. Let the cork float in water in a bowl or a cup. Make sure that the needle does not touch the water. Your compass is now ready to work. Make a note of the direction in which the needle points when the cork is floating. Rotate the cork in different directions with the needle fixed in it. Note the direction in which the needle points when the cork stops rotating. Does the needle always point in the same direction when the cork stops rotating?



Compass in a cup

4. Electric switch: To explain the concept of switch in a simple electric circuit, an improvised version of it can be made using a safety pin. One



An improvised electric switch

can make a switch using two drawing pins, a safety pin (or a paper clip), two wires and a small sheet of thermocol or a wooden board. Insert a drawing pin into the ring at one end of the safety pin and fix it on the thermocol sheet as shown in the adjoining figure. Make sure that the safety pin can be rotated freely. Now, fix the other drawing pin on the thermocol sheet in a way that the free end of the safety pin can touch it. The safety pin fixed in this way would be a switch in this activity.

5. Spirit lamp from a small bottle: An empty small bottle with a metal top may be improvised as a spirit lamp. Make a hole of about 5 to 8 mm diameter in the centre of metallic top of the bottle. Now take a nozzle of old retired tube of bicycle. Fit this nozzle in the hole of metallic lid of the bottle. A wick made from cotton wool is fitted, so that it extends up to the bottom of the bottle. Use spirit (denatured alcohol) as fuel.

6. Focal length of convex lens: Fix a wooden scale of 1.5 metre (or a measuring tape) with a sellotape on the edge of a table. Take three metallic or glass tumblers of equal size. Keep them in inverted position on the table as shown in the adjoining figure. Cut a potato into two halves and place them separately on the two tumblers. Make small groove with a knife on one piece of potato to fix a convex/concave lens/mirror. Similarly on the other piece make the groove to fix a small piece of white paper that can be used as a screen. Place a small candle on the third tumbler. This set-up can be used to discuss the nature, size and position of the images formed by convex lens/concave lens/mirrors and to determine their focal length.

Similarly, focal length of a concave lens using a convex lens; and a concave mirror can also be determined.

Improvisation for finding focal length of a convex lens

ACTIVITY 9.8

Observe the Fig. 9.3 on the next page carefully and make an improvised aluminium foil electroscope. Demonstrate in the class how will you use it to detect a charged body.

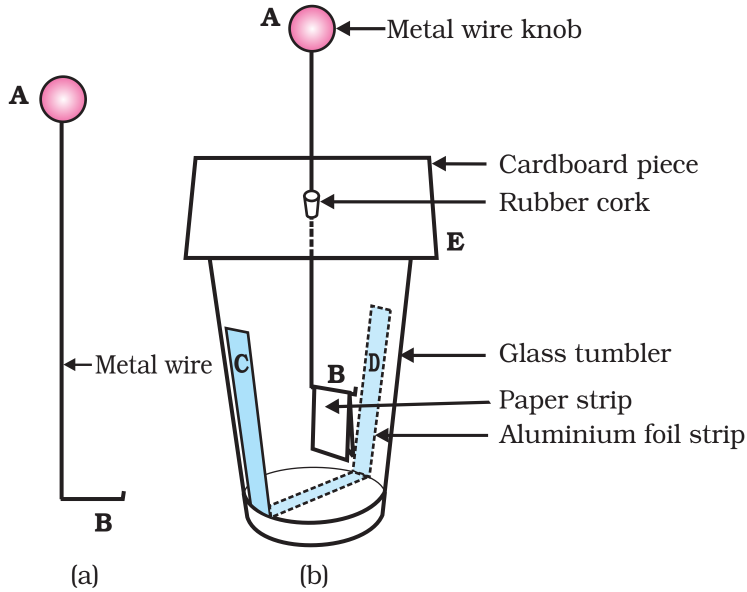


Fig. 9.3 *An improvised electroscope*

9.6 SOME INEXPENSIVE SOURCES OF CHEMICALS

We have seen that many materials from the immediate environment can be used to make improvised apparatus for performing activities and experiments of physics. There are many inexpensive chemicals in our immediate environment that can also be used to perform activities and experiments in chemistry. Students get the opportunity to appreciate the application of chemistry in their everyday life if common household products are used to conduct experiments and activities. Familiar materials provide a context of learning that can be more interesting to students. Teaching-learning begins with the students' existing knowledge that can facilitate their conceptual development. Some inexpensive sources of chemicals are suggested below. Students may volunteer to bring in some of these materials.

Table 9.1 Some inexpensive sources of chemicals

Chemical	**Formula**	**Description**
Aluminium	Al	Aluminium foil
Copper	Cu	Electric wire
Carbon	C	Charcoal used in cooking, activated charcoal used in water purifier.
Iron	Fe	Iron nails, steel wool, screw, nuts, etc.

Chemical	Formula	Description
Hydrogen peroxide	H_2O_2	Hydrogen peroxide is used as an antiseptic which is available at the drug stores.
Iodine	I_2	Tincture of iodine is an antiseptic used for treating wounds. It is available at most drug stores.
Ferric oxide	Fe_2O_3	Ceramic rust is used to add red colour to pottery.
Magnesium hydroxide	$Mg(OH)_2$	Some antacid tablets and milk of magnesia contain magnesium hydroxide.
Magnesium sulphate	$MgSO_4.7H_2O$	Epsom salt is a laxative. It is available at drug stores.
Methanol	CH_3OH	Methanol is used as a solvent of paint. It can be obtained from paint shops under the name 'wood alcohol'.
Mineral oil	Complex mixture of hydrocarbons	Baby oil is essentially a mineral oil.
Paraffin	$CnH_{2n+2}(n>19)$	Candle
Potassium carbonate	K_2CO_3	Potassium carbonate used as fertiliser can be obtained from agricultural supply shop.
Potassium permanganate	$KMnO_4$	Used to purify water and remove cloudness from water. It is also used in aquariums.
Sodium hydrogen carbonate	$NaHCO_3$	Baking soda is pure sodium hydrogen carbonate.
Sodium carbonate	Na_2CO_3	Washing soda is a household material.
Sodium tetraborate decahydrate	$Na_2B_4O_7.10H_2O$	Borax or *suhaga* is available at grocery shop.
Sucrose	$C_{12}H_{22}O_{11}$	Sugar

Chemical	Formula	Description
Sulphuric acid	H_2SO_4	Battery acid, also known as oil of vitriol, is sulphuric acid and may be obtained at motor garage or auto supply shop.
Tungsten	W	The filament in incandescent light bulbs is made of tungsten.

ACTIVITY 9.9

Read a laboratory manual of chemistry to find how to prepare following acid and base stock solutions. Prepare these solutions in the laboratory and present the report of your work in the class.

5.0 M Acetic acid
6.0 M Hydrochloric acid
6.0 M Sodium hydroxide
2.0 M Sulphuric acid
1.0 M Nitric acid

What precautions are required to make the solutions?

9.7 SCIENCE KITS

A major idea of concern in science education is the gradual decline of practical work and experimentation at secondary and higher secondary stages. Also the concept of activity-based teaching- learning is yet to become a reality in many elementary schools. Lack of laboratory facilities and awareness among teachers about activities and experiments being fundamental to doing and learning science can be some of the reasons behind it. The absence of laboratory facilities in school drastically narrows down subject options for students, denying them equal opportunities for learning and future life chances. Hence, it is important to make available resources to such schools to facilitate experimentations. Such schools can benefit largely from science kits. **Science kits are useful not only for schools lacking facilities of a science laboratory, but for all schools as they are convenient to use.** Use of science kits can be very helpful in motivating both teachers and students to integrate hands-on experience of science with day-to-day teaching-learning of science. Design, development, and production of various science kits meant for different stages of learning have been undertaken by many organisations and institutions of the country including NCERT.

For effective teaching-learning of science, it is essential to perform certain activities and experiments in classroom situations. Performance of these activities and experiments requires some special apparatus and materials. When these materials are made available at one place, say in a box, it is referred to as science kit. Most of the apparatus and materials belonging to the kits can be conveniently available in the market while some of them can be improvised. While designing and listing items for science kits, attempts are made to ensure that the tools are not heavy or unsafe for the students. Now let us see its various advantages.

Advantages of science kits

- They provide easy availability of all the materials for performing experiments at one place and are moderately priced. Manuals are also provided with them.
- They save time required for collecting the materials and apparatus each time a teacher wants to perform activity or experiments.
- A large number of activities and experiments can be performed with a few apparatus and materials.
- They are portable and can be used both indoors and outdoors.
- Generally these kits do not require extra source of energy, such as gas, water or electricity supply for their use. Therefore, these can be used in smaller towns, rural areas or other places where other infrastructural facilities are not there.
- The material and the equipment kept in the kits are simple and locally available and are capable of improvisation and repair by the users according to their need. In this way kits may provide opportunity for the development of creativity.
- Students actively take part in handling and doing experiments. Learning by doing encourages self-confidence.
- Pieces of apparatus can be used for several times for various purposes. Kits, therefore, have multipurpose use.

The Workshop Department of NCERT has developed various science kits. These are upper primary science kits, secondary science kits, microscale chemistry laboratory kit at secondary and higher secondary stages (separately), solid state model kit, molecular model kit, etc.

Using microscale chemistry laboratory kit, chemistry experiments can be performed taking small quantity of chemicals without compromising on the quality and standard of experiment. It covers very small storage area. The experiments can be performed very quickly as it saves time for preparation. Cost of the material and equipment are reduced to a significant extent. These are pollution and hazard free. Conventional laboratory racks and bottles are replaced by a small box containing all the small laboratory wares and apparatus and on the top of the box are revolving circular racks to hold plastic bottles that dispense only a few drops of liquid at a time. Four students can work on this kit at a time. The kit is accompanied by a detailed manual describing the use of items and details of each experiment.

Microscale chemistry laboratory kit and science kits

NCERT also organises various orientation and training programmes for the popularisation of these kits.

My name is Thoiba. I facilitate learning science to the students of Class VI and VII in Manipur. I have collected some materials and equipments with the help of my students and laboratory incharge of physics and chemistry for carrying out activities in the class and keep all of them in a bag. The bag is placed in the science laboratory. It facilitates in performing and conducting activities during discussion about the concepts. Sometimes I rearrange seating arrangement of the students for facilitating group work.

I have collected following items in the bag— Metre scale, measuring tape, chart paper, candle, matchbox, thread, rubber bands, balloons, spherical solid of about 2 cm diameter , a wide toothed comb, soap, needle, cork, filter paper, plane mirror, concave mirror, convex mirror, prism, concave lens, convex lens having focal length of 10, 15 and 20 cms respectively, cells, a battery of 3-4 cells, connecting wires, torch bulb, LEDs, improvised switch, tester, magnet, iron filings, magnetic compass, magnetic toys, toy car, iron nails, beaker, test tubes with corks, spirit lamp, measuring cylinder, right angle glass tube, funnel, common salt, sugar, oxalic acid, lime water, copper sulphate and magnesium hydroxide.

I keep on adding and replacing the materials, whenever required. Students volunteer to collect many materials like sample of soils, fabrics, leaves, food items, etc. It saves my time. I have observed students participate more actively in teaching-learning process now.

–Experience of a teacher

ACTIVITY 9.10

Molecular model kit is a self-learning kit. It contains coloured plastic moulded sphere representing various atoms having a number of prongs. Prongs are used to make bonds with other atoms through tubings. Learn to use the molecular model kit to explore the structure of simple organic, inorganic molecules and solids. Discuss in the class how can you use this kit in teaching-learning of chemistry.

9.8 LABORATORY AS A LEARNING RESOURCE

Laboratory work can be used as a powerful learning resource of science. **Laboratory work is based on the principle of learning by doing and it is an integral part of science education.** It helps in better understanding of various concepts of science and construction of knowledge. The first-hand experience obtained through experimental work imprints a permanent impression on the mind of the learners. It provides opportunity to the teacher to inculcate various process skills of science, viz. observation, classification, analysis of data, recording, inferring, generalising and communicating. Process skills so acquired help in developing interests, values, and spirit of inquiry that constitute scientific attitude. Students learn while handling, manipulating and innovating different types of equipments. It provides an environment to learners for exhibiting their qualities such as resourcefulness, initiativeness, orderliness, cooperation, and team spirit. Students enjoy working together with their peers with some freedom of action, having a feel of the excitement of the unknown and achieving a sense of discovery. Of course, learners cannot rediscover all of science; however, encouraging them to observe, investigate and think critically on a laboratory activity can facilitate them to construct some abstract concepts and principles of science, to awaken curiosity about the world around them and to gain a feel and appreciation of science. Thus, laboratory work facilitates development of (i) cognitive abilities, i.e. principles and laws discussed in the classroom may precede or follow the laboratory work or it maybe carried out during discussion;

(ii) process skills of science; (iii) scientific attitude; and (iv) understanding nature of science. Use of laboratory must be focused towards achieving these objectives.

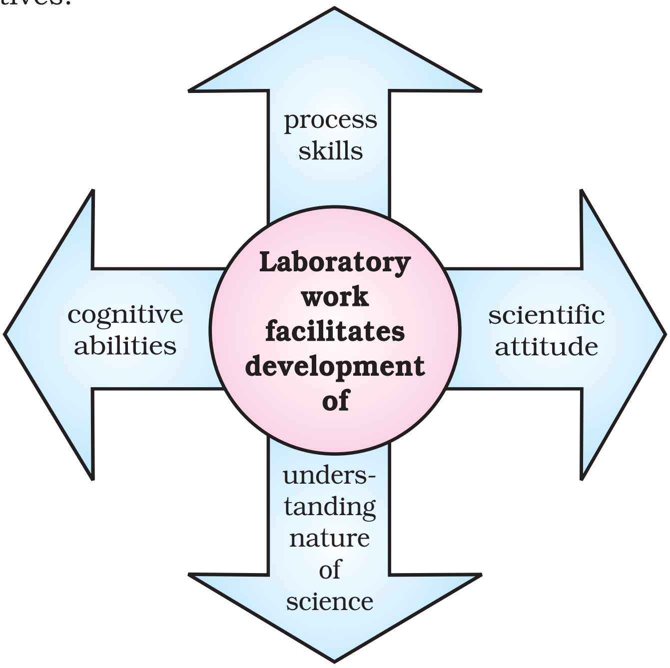


***Fig. 9.4** Objectives of laboratory work*

The kind of experience that is provided by the laboratory cannot be replaced by any other exercise. **Well-planned laboratory experiences have great potential to attract our young generation into science courses.**

Performing experiments in prescribed fashion and just involving students in hands-on activities do not result in development of inquiry skills in science. In Chapter 7 *Pedagogical Shift in Physical Science,* we have understood the importance of inquiry approach in science. Development of inquiry skills cannot be taken for granted as the by-product of the process skills of science. Opportunities to raise question, involving the learners in critical discussion, investigating their own questions and being flexible in the work should be facilitated in the laboratory. Inquiry can be broadly planned considering limited availability of time and crowded classrooms. It is to be kept in mind that **emphasis should be given to the first five letters of LABORATORY rather than the last seven letters.**

9.8.1 Approaches to laboratory work

Deductive approach: It is perhaps the most common approach and used for the verification of concepts, laws and principles of science. The theoretical aspect of the concept is first discussed (e.g. Ohm's law, Archimedes principle) and it is followed by first hand experience. Students can get time to organise their abstract ideas (using mathematics, wherever required) and can acquire meaning of the concepts and find relevance of the laboratory work with their previous understanding.

Inductive approach: Students are provided opportunity to develop concepts, principles and laws through first-hand experience before these ideas are discussed in the class. Students search for patterns, relationship between different quantities and applications of the concepts while engaged in the laboratory work. Their ideas are reinforced during discussion after the laboratory work. This work is immediately followed by discussion for strengthening of their understanding.

Problem solving approach: Learners can be provided opportunities to do open-ended activities and experiments of exploratory nature where they have freedom to explore their ideas. By the time students reach higher secondary stage, they acquire basic technical and inquiry skills. They should be encouraged to identify their own problem, develop hypothesis, design investigation and experiment to solve the problem, collect and organise the data and report their findings. It gives them opportunity to become independent learners, organise their own learning and develop self-confidence. For example, a group of students are interested in knowing, *do oils of higher density have larger value of refractive index?* or *what factors may be responsible for variation of the result in Ohm's law experiments and to what extent?* They should be encouraged to work on their problem. **It is important to mention here that it is not central to reach a concluding result, getting students engaged in the process of inquiry is more important.** We have already understood this in Chapter 1 *Nature of Science* (Section 1.5).

9.8.2 Planning and organising laboratory work

Science teachers must plan laboratory work well in advance for making best uses of available materials and time. A teacher can plan on thinking along the following lines:

- Is the objective of activity/experiment/project work clear to the students?

- How will I facilitate them to perform the experiment?
- Are materials/apparatus available in the laboratory?
- How will I involve learners in setting up the experiments?
- Have I performed the experiment myself to check the functionality of all apparatus?
- Is the procedure simple and can be performed within the allotted time period?
- How will applications of their findings enhance their learning?
- How will I integrate the laboratory experiments with classroom teaching-learning experiences?

The learning experiences in the laboratory should provide some challenge to the students to learn. They get interested if they understand the purpose of the experiment and are made to realise the application of it to their everyday life.

Students can be involved in planning and organising various works of laboratory. Following guidelines for planning and organising experiments in physical science may be considered.

- It should be ensured that students have a sound theoretical knowledge required for handling the apparatus and performing the experimental work. For this, theory and practical teaching-learning situations should be properly integrated and coordinated.

Open-ended activities and experiments provide students freedom to explore their ideas

- Students should come prepared for the laboratory work. They should be encouraged to refer laboratory manual and other supplementary materials. They should be facilitated to find answers to their own questions.

- Enough apparatus should be set up to provide opportunity to all learners on hands-on activities. It should be checked that the apparatus are in proper working condition.
- **During the laboratory work, extensive and critical discussion on the theoretical aspects of the experiments with the students and continuous assessment of their performance are of utmost importance.** This helps the teacher to know their misconceptions and naive concepts and she can then facilitate them in the construction and reconstruction of their knowledge.
- A noticeboard to display safety rules of the laboratory, time- table, list of experiments, group patterns, etc. can be maintained and kept up to date.
- Good discipline is necessary for smooth functioning of the laboratory work.
- Maintaining all possible standards of safety in the laboratory and inculcating safety conscious attitude in students are important.
- Safety kits such as fire extinguishers, sand bucket, rubber gloves, separate dustbins for dry and wet waste materials, etc. should be kept handy.
- First-aid box must be kept ready and timely replenishment of medicines must be ensured.
- **Remember that safety of the students and teachers is more important than the safety of the apparatus.**

Generally, in the beginning of the session, the teacher takes the students around the laboratory to familarise them with the general facilities, equipment, apparatus, chemicals, glassware, etc. available in the laboratory and informs them about certain do's and don'ts while working in the laboratory.

We shall discuss on safety issues in detail in section 9.8.5.

9.8.3 Working in group in the laboratory

Students can be grouped into different ways depending upon the equipments available in the laboratory. Two examples are given below.

1. All the students may work on the same equipment at the same time (Table 9.2). The arrangement is convenient for the teacher, as general guidelines to the entire class can be given at a time, but it is feasible only if strength of the class is less.

Class IX

Table 9.2 Laboratory plan for Batch I

Date	Name of the experiment
...(first week)	To determine boiling point of water.
...(second week)	To study the changes in state of sublimate solids on heating.
...(third week)	To study third law of motion using two spring balances.
...(fourth week)	To verify Archimedes's principle.

2. If the number of students is more, the teacher may facilitate the class to form 4 – 6 groups. Each group maybe allotted different experiment in a cyclic manner. Students in each group may perform the experiment either individually or in pairs, i.e. two or more pairs of students may work on the same experiments separately (Table 9.3).

After performing experiment number 1, group I shifts to experiment 2, group II shifts to experiment number 3 and so on. In this type of arrangement, teacher has to give different types of guidelines to each group separately. Supervision of the various experiments being carried out in the laboratory needs to be done simultaneously.

Class XII

Table 9.3 Laboratory plan for a batch of four groups of students

Group	Roll No.	Name of the experiment
I	1 – 5	To verify Ohm's law.
II	6 – 10	To verify laws of combination of resistances using a metre bridge.
III	11 – 15	To determine the internal resistances of a primary cell using a potentiometer.
IV	16 – 20	To determine resistance of a galvanometer by half deflection method.

Teacher can maintain a record of date of allotment of experiment to each student and date of its completion for her reference and follow-up action.

9.8.4 Motivating students to maintain the regular record of laboratory work

- Students should be instructed to maintain and bring the following in the laboratory:
  - (i) Auxiliary record book in which preliminary work for the experiments such as drawing ray diagram/circuit diagram, observation table, writing chemical reaction, etc. is done. Observation of the experiment performed should be recorded in it. Students should be encouraged to record observations and interpretation of the result in their own way/words.
  - (ii) Laboratory notebook for keeping the systematic and methodical records of the experiments.
- Students should keep in mind that proper plan for recording the observation should be made. Whenever possible, observations should be represented with the help of diagrams and graphs.
- Teacher should ensure that observations are recorded in the auxiliary notebook in the laboratory itself.
- Students should be encouraged to learn to distinguish inferences from their observations. Also, they should have understanding of the relevant concepts, principle and theory to interprete the result.
- After getting checked the observations, calculation and result in the auxiliary notebook by their science teacher, students should make a final record in the laboratory notebook of the experiment performed. Index table should be duly filled up. Regularity in the submission of laboratory record book should be ensured.
- A few words of appreciation can encourage students to maintain regularity.
- Learning Indicators (LI) for various experiments can be identified involving the students and the tasks specific to the experiment should be assessed during each experiment. Oral test should also be conducted during each experiment, and grade can be given. Chapter 11 discusses on Learning Indicators (LI) and performance based assessment. [see section 11.4(B)]

9.8.5 Safety in laboratories

One of the important duties of science teacher is to develop safety conscious attitudes and safe personal habits in students. Students need to learn about safety in the laboratory by being instructed about

SAFETY RULES TO BE FOLLOWED IN PHYSICS LABORATORY
1. Enter the laboratory in the presence of the teacher and follow all safety instructions. 2. Always follow the precautions suggested by the teacher for individual experiment and activity. 3. Do not work with all doors and windows closed. 4. Do not touch the electric switches with wet hands. 5. Throw water and chemicals at proper places, not on the table or floor. 6. In case of fire or smoke or any accident in the laboratory, inform the concerned teacher immediately. 7. Do not play with any apparatus, it may lead to an accident. 8. Never try any secret experiment.

the hazards rather than by experiencing them. They should be given explanation of the laboratory safety rules with reasoning. They should be warned of any specific hazard when it is likely to arise. The layout of the laboratory should be such that teacher is able to oversee the activities of all the students in the class. The location of water, gas, electricity main control, and fire fighting equipment should be at the proper and convenient place. She should have rapid access to the site if any incident occurs. Above all, teacher should avoid getting stuck at a place. She should move around the classroom to offer suggestions to those who are confused as how to use an equipment. All reasonable precautions in the performance of laboratory work should be taken. Lesson should be planned in such a way that all the hazards are minimised. Some common potential hazards in physics and chemistry laboratories are discussed below:

(i) Mechanical and glassware hazards

All equipments with moving parts constitute a hazard if they are misused or fail to operate properly. Wherever possible, moving part of the apparatus should be guarded properly.

Some precautionary measures

- Students should be instructed to stay away from the heavy slotted weights hanging from the apparatus, such as sonometer.
- Large glass containers must be handled by the neck. Proper care should be taken in storing the apparatus.
- Reagents likely to react vigorously with each other should be kept as far apart as possible. Liquids placed in spherical containers

can act as a lens, focusing enough sunlight to cause a fire. They should be kept in dark.

- Broken glass pieces can be cleaned with the aid of some plasticine.
- Glass tubing should be cut with a file or glass knife, the hands being protected by a cloth. It should be carried vertically.
- Wherever possible, glass materials may be replaced by a less hazardous alternative, e.g. plastic bowls and measuring cylinders.
- Glass stoppers which have become jammed should be loosened by tapping gently with a wooden block wrapped in a soft cloth or if the bottle contents are appropriate, by running warm water over the neck of the bottle.
- Experiments involving the heating of solutions should be done in pyrex glassware, not in ordinary glassware.

(ii) Electrical hazards

The obvious danger in using electrical equipment is that of electric shock and fire hazards. The electrical resistance of the body varies enormously from one individual to another and within the same person under different conditions. The resistance is very low if the skin is moist. A current of 100 mA through the body can be fatal. A higher current can also produce burning.

Some precautionary measures

- The electric power supply or the electrical outlet in the physics laboratory should be sufficient in number, properly insulated, in excellent working order, properly grounded, and inspected routinely by qualified electricians.
- Wherever electrical outlets are not available, extension cords that are as short as possible and insulated properly for that particular voltage and current should be used.
- Equipment should carry a distinctive on/off light.
- The range of the measuring instruments should be properly marked and the students should understand the meaning of the range properly.
- Wearing metal rings, necklaces, using metallic prongs, pencils, rulers, etc. should be avoided while working with switched-on electrical equipment and apparatus.
- Service of electrical appliances, devices and apparatus should always be done by qualified experts.

- Hands and bench should be kept dried and long trailing leads and makeshift connections should be avoided in the experiments.

(iii) Toxical hazards

It would be better to treat all chemicals as though they were poisonous, as range of toxic substances is greater than those declared officially.

Some precautionary measures

- All the chemicals should be adequately labelled.
- Careful supervision is required in the use of caustic and corrosive substances.
- Ingestion of chemicals is most likely to arise from pipetting by mouth. Vigil should be kept on the students.
- Gases, vapours, fine spray and fumes of toxic materials may enter in the body by inhalation. Therefore, it is of utmost importance to use right techniques of performing the experiment and having provision of cross ventilation in the laboratory.
- Special care must be taken in some of the experiments, such as benzene should be replaced by methylbenzene, wherever possible; chlorine gas should not be prepared in large quantities on an open bench.
- Children are inquisitive by nature. It should be ensured that they do not touch or smell the toxic substances. They should be made aware of the harmful effect of those materials.

What if ...

In spite of taking all the precautions and minimising the risks, what to do if accident occurs? The most important consideration is to act quickly, quietly and methodically without being panic stricken.

It will be too late to think about procedure after an accident has happened. Keep the first aid box handy. A list of common accidents and their remedies approved by a good doctor should be hung on one side of the first aid cupboard, so that the right medicine can be applied in case of certain accident. However, the purpose of first aid is not to substitute doctor's treatment, but to ensure that no further deterioration occurs. Following steps should be taken:

- Remove the injured person(s) from further hazard. This might be disconnecting electrical supply, gas or water or removing from fire, etc.

- Apply first aid immediately.
- If necessary, seek the help of your colleague to control the class.
- Inform the school office of the accident for making arrangement of medical care.
- After the accident, submit a written report to administration stating the facts.
- Some other actions may be necessary to take, such as calling a fire brigade, evacuating the class into open air, etc.

Lastly it should be remembered that **prevention is better than cure**.

Let us now perform the following activities before having a discussion on the maintenance of chemistry laboratory and physics laboratory for their optimum utilisation as learning resources.

ACTIVITY 9.11

Visit a nearby school and observe how does the teacher of physics/chemistry plan and organise her laboratory work. Talk to her to collect information about the precautionary measures she takes for the safety of students. Present your report in the class.

ACTIVITY 9.12

Make a poster giving the message of precautionary safety measures one should take while working in a physics/chemistry laboratory.

9.8.6 Chemistry laboratory

A chemistry laboratory should have suitable and safe storage of chemicals, adequate supply of water and gas, proper drainage system and proper working tables with waterproof and acid proof tops for performing experiments using various equipments and apparatus. There should be provision of reagent racks, fume cupboard and good ventilation having exhaust fans in the laboratory.

We will discuss how to manage a chemistry laboratory and handle chemicals, apparatus, heating devices apart from working space for conducting experiments and activities.

(a) Chemical: A large number of chemicals are made available in a chemistry laboratory for doing experiments. These chemicals are available as solids, liquids or their solutions. Whatever chemicals are required for a particular experiment, these should be made ready one day before the day of experiment to be performed by the students. Teacher must also see that the chemicals are in sufficient amount. Let us take the example of an experiment in which concentration (strength) of a given sodium hydroxide solution is to be determined by titrating it against a standard solution of oxalic acid.

The chemicals required are oxalic acid, sodium hydroxide and phenolphthalein. All the three chemicals are used in the experiment as solutions. Therefore, teacher must know how the solutions of these chemicals are prepared, what should be the normality or strength of these solutions, how much chemical is required to prepare a solution for a particular group of students. At the same time, teacher should also know— how to store the solutions, how to distribute these solutions amongst students at the time of practical class and what to do with leftover solution.

(b) Apparatus: The apparatus required for the experiments include burette, pipette, conical flask, burette stand, funnel, measuring flask and a white glazed tile. The glass apparatus must be neat and clean. Teacher must see to it that the required apparatus is available in the laboratory for the group of students. She must know how to instruct students to clean and dry glass apparatus before using them. The setting of apparatus is another important part of every experiment. This particular experiment of titration involves:

- clamping of the burette vertically in a burette stand;
- filling of sodium hydroxide solution into the burette and removal of air gap (if any) from the nozzle of the burette;
- observing the initial reading of the burette. It may be zero or it may be some other reading suitable for the students;
- observing readings of the burette which is very important. Student's eye should be exactly at the same level as the meniscus of the solution.
- filling of pipette with standard oxalic acid solution and then transferring this solution to the conical flask;
- adding phenolphthalein to the conical flask before starting the titration. It is used as an indicator and the knowledge about the quantity to be added must be known to the teacher. In this case, 2-3 drops are sufficient; and
- Observing end point which is quite important in such type of experiments. In this case after adding sodium hydroxide solution slowly in the oxalic acid solution of flask, a faint permanent pink colour is obtained.

All these steps of the experiment involve proper use and handling of the apparatus with which the teacher must be thoroughly acquainted.

(c) Heating devices: In a chemistry laboratory, heating of substances/ solutions is required during a number of experiments, especially during the chemical analysis of salts and their mixtures for detecting cations and anions present in them. Heating increases the speed of a chemical reaction.

The heating devices available may be gas burner (usually Bunsen burner), spirit lamp or kerosene lamp. Teacher must know every detail about these heating devices. She must know how to adjust the air flow of a Bunsen burner to get a non-luminous (blue coloured and non-smoky) flame. If the flow of air is not properly adjusted or the air vent of the burner is closed, it will give a yellow coloured smoky flame. Such a flame is not suitable for proper heating and will make the test tube, flask or beaker to be heated black. Sometimes the flame starts to strike back and burn at the nozzle near the base. This makes the burner very hot. It happens due to fully opened air vent. In such a situation, put off the burner, cool it and then ignite it again and adjust the air vent to get a proper non-luminous flame.

In using various heating devices, it is equally important to know how to put off a flame. A lighted heating device should not be put off by blowing at the flame. In case of Bunsen burner the supply of gas is turned off, in case of a spirit lamp, burning wick is covered with the help of a metallic cover and in case of kerosene lamp the outer sleeve is covered by a metallic or asbestos sheet.

(d) Glass tube and glass rods: Both glass tubes and glass rods are used in chemistry experiments. The glass rods are used for mixing, stirring and transferring of chemicals and their solutions. The glass tubes are used in passing gas into solutions. Many times, we need to cut glass rods and glass tubes to obtain their desired length. The glass tubes are bent also by heating them to get a desired shape. Thus, a teacher must be familiar with the technique of cutting and bending of glass rods and tubes and then rounding/smoothing the freshly cut edges.

(e) Weighing balance: In a number of experiments in chemistry, approximate or accurate weights of substances are required. For weighing substances, different kinds of physical and chemical balances are used. Now-a-days digital balances are also in use. Chemical balances give exact weight of substances. Generally the analytical balance used in a chemical laboratory may give exact weight up to fourth decimal place. A teacher must know all details of using and maintaining these balances. Some of the important precautions in using the balances are given here.

- Every balance has a capacity of weight. Therefore avoid overloading balance while weighing.
- Never weigh a hot substance.
- Keep the pans of the balance neat and clean.
- Check the balance before weighing any object. Make necessary adjustment, if required.
- Observe the reading of weight very carefully before noting it down.

(f) Setting of apparatus for various experiments: Various types of apparatus are used in different chemical experiments. Teacher must be well-versed in setting up of the apparatus.

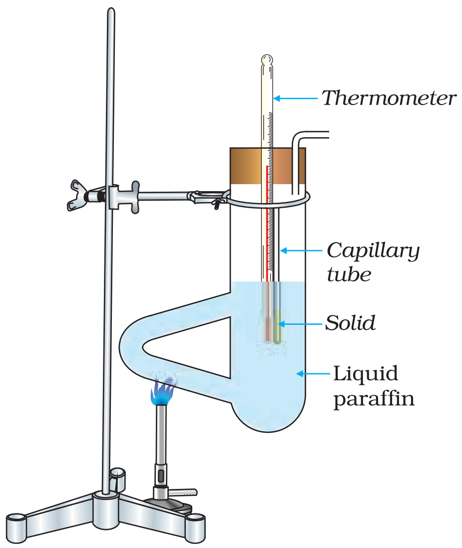


Fig. 9.5 *Thiele's tube*

For example, in the experiment of determining the melting point of a solid organic compound, the compound is filled in a capillary tube and then attached to the laboratory thermometer. This set is then fixed in a Thiele's tube, as shown in Figure 9.5. A number of precautions are required while setting and handling this apparatus. Following precautions should be taken for the experiment mentioned here.

(i) All the glass apparatus must be neat and clean.

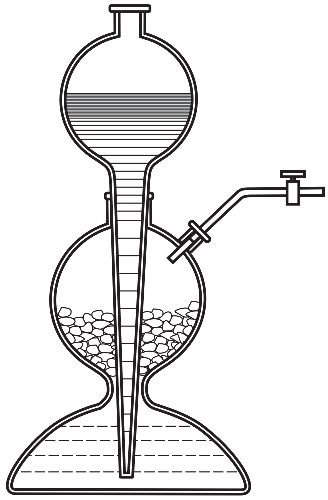
(ii) Keep the lower end of the capillary tube containing organic compound and the bulb of the thermometer at the same level.

(iii) The cork of the Thiele's tube holding the thermometer should have a side groove so that the vapours can escape through it during the heating of the liquid. Otherwise the tube or flask may burst due to high vapour pressure build inside these containers.

(iv) The Thiele's tube should be filled with liquid just above the upper end of the side arm.

(v) Generally concentrated sulphuric acid is used as the liquid mentioned above, which can be heated up to 280^0C. However, it is safer to use liquid paraffin in place of sulphuric acid, which can be safely heated up to 220^0C. Silicon oils (if available) are the most suitable liquids for these experiments.

(g) Solutions: In chemistry laboratory many chemicals are used in the form of solutions. In experiments related to titrimetric analysis a variety of solutions are used. These are termed as standard solutions, molar solutions, normal solutions, etc. The teacher must know how to prepare these solutions. Methods of preparing these solutions are given in details in the laboratory manuals. One must also be very clear about the primary and secondary standards. It is also important to know how to prepare solutions of indicators like phenolphthalein, methyl orange, etc. for the acid base titrations and other experiments of titrimetric analysis.



Kipp's apparatus

(h) Use of Kipp's apparatus: Qualitative analysis is done to find out nature of substances and to identify their constituents. For example, in the qualitative analysis of inorganic salt or mixture of salts the cations (such as Cu^{2+}, Ca^{2+}, Mg^{2+}, etc.) and anions (such as Co_3^{2-}, Cl^-, So_4^{2-}, etc.) are identified. In the analysis of certain cations H_2S gas is passed in their solutions. Kipp's apparatus is generally used to prepare H_2S gas. Teacher must know how to set up the Kipp's apparatus to prepare the gas, even if the gas is prepared by a laboratory attendant.

(i) The basic concepts of experimental chemistry: Teacher must be well versed with the basic concepts of all the experiments to be done in the school laboratory. She must be able to answer any question or problem which arises during the course of an experiment. Some examples are given here.

- Why are the burette and the pipette rinsed with the solution with which these are filled?
- Why should the last drop of the solution not be blown out of a pipette?
- Why can we not prepare a standard solution of HCl, H_2SO_4 or HNO_3 directly?
- Why is dilute H_2SO_4 preferred over dilute HCl while testing anions?
- Why is silver nitrate solution stored in dark coloured bottle?
- Why is it essential to boil off H_2S gas before precipitation of cations of third group of qualitative analysis?

Similarly there can be many more questions, whose answers the students should know with the help of the teacher.

9.8.7 Physics laboratory

Essential facilities of a physics laboratory include adequate number of electrical outlets, dark room facility for optics experiments, adequate storage space for all types of apparatus and equipment, space for carrying out project work, sufficient light and proper ventilation.

A physics laboratory can be used as a learning resource in various ways, such as verification of results of earlier experiment; development of concepts, principles and laws discussed in the classroom— may be during the discussion or preceded or followed by the discussion; problem solving, project work, etc. A physics laboratory needs to be looked after to cater to all such needs.

Most of the times we have been using physics laboratory in the context of verification of certain results prescribed as part of physics practical syllabus. In the previous chapters we have understood about the importance of inquiry and investigations in teaching-learning of science. Laboratory resources need to be used effectively for these purposes also. In many schools, student and teacher ratio is so high that sometimes it is not feasible for the teachers to organise experimental activities involving students in individual practical work. In such situations group work should be encouraged. Teachers should be adequately trained in carrying out laboratory work and the skills required for working in physics laboratory.

Skills essential for working in the physics laboratory

Some of the essential skills for working in the physics laboratory are: taking measurements using various instruments such as vernier calipers, screw gauge, travelling microscope, etc.; connecting electrical devices; soldering of electrical connections; using electric meters; working with images in mirrors and lenses and taking required measurements; using watches and clocks; measuring weight with different types of balance; locating magnetic poles in permanent magnets; constructing temporary magnets; using cells and batteries; and plotting and interpreting graphs. Teachers should acquire proficiency in such skills and facilitate learners to learn many such skills.

Teachers should have understanding of calculation of different types of error occurring during the course of experiment and their correction. These may be identified and taken care of as personal or chance error, error due to external cause, such as room temperature, pressure, etc. or instrumental error of the apparatus.

ACTIVITY 9.13

(i) Assess yourself from the point of view of various skills required for maintaining and using a physics laboratory as learning resource. What skills do you have and what other skills do you need to learn?

(ii) Perform related activities/experiment in the laboratory of your college or nearby school to acquire those skills. You may take help of your classmates and the teacher-educator to achieve proficiency in those skills. Present your report in the class.

Apparatus: Apparatus should be arranged in proper order in the laboratory. To avoid any damage, all apparatus should be handled carefully and cautiously. Most of the appliances, apparatus, devices, instruments and materials used in the laboratory come with some guidelines on how, when and why to use them with proper instructions of handling and care. These guidelines may be very helpful in designing the experiences for the learners and should be consulted even if the teacher is sure that she knows everything related to the work to be done in the laboratory. Precautions suggested while using a particular apparatus should be observed strictly. Teacher must be well versed in setting up various experiments.

A **pre-laboratory session** can be a good idea in developing a framework for working in a physics laboratory. This prepares learners for the activity and issues related to safety of apparatus to be used and their own safety also. A pre-laboratory session can be helpful in making the context of the concept and the approach (inductive, deductive or problem solving) to be followed. For example, following problem solving approach in the case of Ohm's law, discussion can be carried out on the issues of various conceptual clarity on Ohm's law, apparatus and arrangement needed in the investigation, availability and ways of using of those apparatus and arrangement, need for improvisation, if any, etc.

Just like pre-laboratory discussion, **post laboratory session** may be helpful in enhancing the learners' understanding of content and processes in physics, identification of learners' misconceptions and naive concepts, difficulties faced by them and whether they were successful in their pursuit, how did they arrive at their conclusions and results, how did they make interpretations of the result, etc. We have already studied some of these in Chapter 5 *Exploring Learners*. Such post-laboratory discussion might be helpful in exploring learners also. Students should provide reasoning for observing various precautions rather than following them mechanically.

The above cited guidelines for working in a physics laboratory are not exhaustive in nature. Depending upon the framework in which physics laboratory is being utilised as a learning resource, issues like nature of the resources needed, number of learners working simultaneously, etc. may arise.

ACTIVITY 9.14

Select any experiment of physics/chemistry from the syllabus at higher secondary stage. Discuss with your friends in a group to plan pre-laboratory and post-laboratory session with your students on this experiment.

ACTIVITY 9.15

Visit physics and chemistry laboratory of a nearby school to observe how these laboratories are being used as learning resources. Present report of your work in the class.

ACTIVITY 9.16

Visit a scientific instruments dealer shop to observe various instruments of different range. Discuss your observation with your classmates.

9.9 HANDLING HURDLES IN UTILISATION OF RESOURCES

Salma, Maria, and Rahul all very enthusiastic science teachers, wished they could perform activities and experiments and use innovative strategies for teaching-learning of their students. However, sometimes they felt frustrated as they had to face lot of problems in teaching-learning situations. One day, they were discussing about all such problems. Maria said, "All these problems are our problems and we have to find the solutions ourselves." They started writing the problems they faced and noting down them as hurdles. They understood that all this was a matter of proper planning. A positive mindset is necessary to bring about a change. Discussing with each other, they planned how to handle those problems.

What we can do...

Hurdles	How to handle
1. Our course lags behind if	We can plan our activities well in advance

Hurdles	How to handle
activities are carried out in the class.	and involve students. Every activity should be followed by recording observations, conclusions and discussions. In fact, the students get motivated and concepts are developed faster by carrying out the activities.
2. The skewed student-teacher ratio does not give opportunity to every student to utilise the resources in our class.	We may help the class to form small groups. We can ensure contribution of each member of the group.
3. Indiscipline among students while the teacher/student is using the resource.	They need to be actively involved. We can encourage them to ask and answer questions. We can give some students the tasks such as collecting and distributing equipment, materials and apparatus.
4. We have to conduct activity and experiment single-handedly without a laboratory attendant or with an untrained laboratory attendant.	We can train the laboratory attendant ourselves and encourage him/her to gain expertise.
5. We find a time constraint in utilising the resources. Sometimes the time available (1 period) for using a particular resource in school is not enough.	We may ask for clubbed periods on one day of the week to perform activities. We may utilise the time of 'arrangement period' that we get.
6. We do not know what apparatus and materials are available in the laboratories of our school.	A list of resources available in a particular department may be displayed at a prominent place/noticeboard for their maximum utilisation.
7. We spend a lot of time searching for the resources in the	We can give in advance, a list of requirements to the laboratory incharge/ laboratory attendant beforehand (prior

Hurdles	How to handle
laboratory/resource room.	day or before first period starts). Equipments and materials can be collected when the class starts.
8. We have apprehensions about using hazardous resources like fire/flame/ sodium metal/ poisonous gases/ electrical wires and harmful chemicals.	We can inform, warn and train the students beforehand about the hazards of using such resources and the precautions to be taken.
9. We face problems in getting the supply of sheets/paper xeroxed	We can use online ICT tools like blog and wikiclass, tutor, group e-mail, etc. to decrease the paper consumption.
10. Mostly we are unable to find time or opportunity to do collective reference work with our students in the library. This is due to the preoccupation of the librarian or students.	Whenever we are not preoccupied and students of our class are engaged in the library, we can visit library for the collective reference work. We can encourage students to become autonomous learners.
11. We remain engaged in teaching-learning within the four walls of the school as there is less opportunity for going beyond the classroom/ school campus.	We can make a school calendar for the current year in consultation with the school authorities. A Table comprising field visits to be made by each class in one academic year may be incorporated in school calendar.

Science teachers may face many hurdles in utilisation of various learning resources. The nature of hurdles and problems may vary from place to place. Only the concerned teacher can view the hurdles faced by her from all angles. What is needed is commitment to identify and utilise various learning resoures for effective teaching-learning of physical science by solving the problems coming on the way.

ACTIVITY 9.17

Talk to an in-service teacher of physical science to find what hurdles does she face in utilising various learning resources and how does she manage to handle those hurdles.

ACTIVITY 9.18

Did you face any hurdle in the utilisation of learning resource during your practice teaching? How did you handle them? Share your experiences in the class.

9.10 SUMMARY

It is important to make the boundary between the school and the learners' natural world porous. Interacting with different resources of community and environment, learners inquire things on their own, interact with peers and adults and use language and vocabulary of science to express themselves. It can help in understanding the concepts of science and reduce rote memorisation. At the same time, it minimises their stress and enhances their self-confidence. Students construct their knowledge the way they view the world. Knowledge in the school and outside the school becomes part of their knowledge framework and they learn to apply it to their daily life. Restriction of classroom activities to what is written in the textbook implies a serious impediment to the growth of students' interest and capabilities. **The immediate environment of the learners and the community are full of immense and exciting learning possibilities.** Teachers need to explore all such possibilities for the enrichment of teaching-learning experiences and providing students the opportunity of independent thinking. However, a meticulous planning is required to find the ways of harnessing various community resources of learning in order to avoid hurdles on the way and superficiality of teaching-learning activities. Teacher can consider a number of approaches and strategies to transact the concepts using those resources of learning. It will be a good idea to make an inventory of local learning resources correlating the concepts of physical science in the beginning of the session. Teachers can take help of their colleagues and students in this planning. **Collaboration of time and expertise within school, between school and parents, between different schools, between schools and external specialist should be encouraged and promoted.**

Improvised apparatus and science kit can be of great help in improving condition of experimental work in schools. Many schools, particularly those in rural areas, are poorly equipped with science laboratories. The absence of such facilities drastically narrows down subject option for students, denying them equal opportunities for learning and future life challenges. It is hence important that adequate

facilities and resources are made available for all laboratories. While elementary schools can benefit from a science corner, secondary and higher secondary schools require well- equipped laboratories. Teachers of physical science should have proficiency in a number of skills required for smooth functioning and managing of laboratory work. They need to be resourceful enough to organise and provide first-hand learning experiences of physical science to students. They should be guided by their knowledge of the learning needs of their students and feel empowered to use a variety of resources of the school and the community. **However, for effective utilisation of community and school resources including the laboratory in the teaching-learning of physical science, it is essential that teacher enjoys a measure of autonomy and flexibility.** This can foster the spirit of exploration and innovation in the teachers. In the next chapter, we shall discuss on the Print and Information and Communication Technology (ICT) as learning resources in physical science.

EXERCISE

9.1 What is the importance and need of using community as a learning resource of physical science? Discuss how various community resources can be used in teaching-learning of physical science.

9.2 'Imaginative use of resources in immediate environment directly affects the quality of science education.' Discuss.

9.3 Discuss the importance of improvised apparatus and science kits in teaching-learning of physical science. What are the advantages of using science kits?

9.4. Taking examples from physical science for each of the following areas of learning, discuss how laboratory work can facilitate development of (i) cognitive abilities of learners (ii) process skills of science (iii) scientific attitude (iv) understanding nature of science.

9.5 How will you plan and organise physics/chemistry laboratory work for thirty students of Class XII? How will you motivate them to maintain regular record of laboratory work?

9.6 Discuss what precautionary measures should a physical science teacher take to minimise potential hazards in the laboratory.

9.7 Explain how will you maintain a laboratory for its smooth functioning and optimising its use in teaching-learning of physics/chemistry.

9.8 Explain how can you transact the concepts of 'Ohms law' and 'focal length of spherical mirrors' by facilitating students to work in the laboratory through each of the following approaches: (i) deductive approach, (ii) inductive approach and (iii) problem solving approach?

9.9 Problems faced by a teacher in utilising various learning resources can be solved by the teacher herself. Discuss with a few examples in the light of your experience as a practising teacher.

9.10 Analyse a textbook of science from the point of view of the flexibility in the use of materials for performing the activities and adaptability to local learning resources. Do you think some change is required? What change might you make to fit to the teaching-learning situations in your school/area? Explain.

NOTES