Teaching of Physical Science

Theory, Perspectives & Practice

K. M. Rajan
Sindhu B. S.
Josen George
Sibu G. Netto
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Fr. K. M. Rajan M.Sc.; M.Ed; Ph.D.
Sindhu B. S. M.Sc; M.A.; M.Ed.
Josen George M.Sc.; M.A.; M.Ed.
Sibu G. Netto M.Sc.; M.Ed.
Sajan R. K. M.Sc.; M.Ed.

St. Joseph's Training College
Mannanam, Kottayam - 686 561

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CONTENTS

Preface

Most would agree that the physical science teaching in schools need to be restructured to address the unprecedented challenges of our educational system. Some argue for activity-oriented approach, others call for problem-based learning, and still others contend that schools should be held more accountable to their clients, and so on.

This book offers a comprehensive examination of the many varied proposals for improving the standards of science education. The book details the theory and practice relevant to physical science teaching. The ultimate purpose of this work is to help science teachers put their ideas to use in their classes. The authors have included samples of lesson plan, unit plan, year plan, blue-print, etc. to help the student-teachers, and other practitioners in the field.

Authors

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Authors

Chapter I
SCIENCE AND EDUCATION

The word science comes from the Latin word '*scientia*' that means knowledge (Barnhart, 1988). The view of science implied here is that science is a body of knowledge. The facts and laws of science paint only a partial picture of the whole enterprise. A complete depiction of science should include the knowledge of the field and what the body of knowledge can provide in the process of understanding (Krug, 1960). Reflecting on the question of science, Galileo Galilee said that the authority of a thousand is not worth the humble reasoning of a single individual. While learning science the learner develops certain faculties through reasoning and experimentation, which no other subject can provide. Theories of science that we accept at any given time are chosen because they function significantly in the process of knowing rather than as factual representation of some reality (Ross, 1971). Science is an on-going process of refining knowledge and "the scientific knowledge is tentative - - affected by the process used in its construction…" (Welch, Klopfer, Aikenhead & Robinson, 1981).

Science always plays a tremendous role in human life. It changes the entire existence of human beings in such important aspects as health, communication, transportation, and power. To visualise the effect of scientific development just look around in a modern room. For example, the curtain and carpets tinted with dyes, which are not natural products - - the chemists have prepared these from coal tar. From the same coal tar, fountain pen ink is produced. The artificial silk fabric of sofa covers has been made from wood pulp. The electric light, nickel-plated door fittings, etc. are all feats (important achievements) of science. The modern world itself is made and maintained by science. We even owe our existence to science.

Kothari commission has remarked, "Science is universal so can be its benefits. Its material benefits are immense and far-reaching - industrialisation of agriculture and release of nuclear energy are two examples - but even more profound is its contribution to culture" (Report of the Education Commission 1964-66, 1966).

Definitions of Science

Albert Einstein, the celebrated physicist, described science as an attempt to make the chaotic diversity of our sense experience correspond to logically uniform system of thought. The literature provides a good number of definitions for science, a few of them are discussed below.

According to Good (1945), "science is an activity by means of which a person seeks to relate his current sense experience to his total structure of understanding in a manner that is in agreement with all his pertinent observations of properties and behaviour."

Columbia Encyclopaedia defines science as "an accumulated and systematised learning in general usage restricted to natural phenomena." According to Aldous Huxley, "science is nothing but systematised and organised common sense" (cited in Rajan, 1999).

Griggs opined that "in the literal sense, science means the pursuit of knowledge, but it has a wider connotation for our purpose and can be said to mean knowledge of nature in the widest possible form. This includes nature study, physics, astronomy, meteorology and much more." It is equally important to look beyond definitions and see what science includes. The following aspects are of utmost importance as far as science is concerned.

1. Direct and indirect observations
2. Scientific inquiry- - asking questions
3. Drawing of inference from evidence
4. Recording observations
5. Developing ways and means to find answers

6. Classification and checking evidences

According to Science Manpower Project, "science is a cumulative and endless series of empirical observations which result in the formulation of concepts and theories, with both concepts and theories being subjected to modification in the light of further empirical observations. Science is both a body of knowledge and a process of acquiring and refining knowledge" (cited in Sharma, 1996). Therefore, it can be inferred that science is a body of knowledge and a continuous self-evaluative process of enquiry. A popular conception of science is that it is either a product or a process. The dichotomisation of science into product (a body of knowledge) and process (a process of knowing) is a distortion of the nature of science, because the process of knowing is inseparable from what is known (Robinson, 1968). The process of knowing and the knowledge used in the process of knowing are equally important. The value of what we know is equally important in our efforts to understand things. Therefore, science should be considered as both a product and a process - - for process would not be meaningful without product. Science can also be defined as "what scientists do" (Sharma, 1996). Based on what scientists do, it is possible to identify at least three things that characterise scientists' work - - descriptions, explanations and predictions.

Science as a Product

The notion of science as a product implies that science is an accumulation of established facts, concepts, generalisations, principles, theories, etc. Thus, the logical and technical outcomes of science can be termed as the product of science. For example, when a concept, theory, principle or law is formulated, it is said to be the logical outcome of science while scientific inventions can be considered as the technical outcomes of science.

The content of science is so voluminous that it is impossible for any one to learn it entirely. Educationalists thought over this difficulty and tried to make learning science easy and natural by systematising scientific knowledge. They categorised and reduced the whole knowledge into certain basic ideas and broad understandings or conceptual schemes. This made learning science simple and natural.

The areas of scientific knowledge significant for human learning are referred to as functional understanding, which consists of scientific vocabulary, scientific facts, scientific concepts, conceptual scheme and application of the above to new phenomena. Psychologists like Piaget, Bruner, Gagne, Ausubel, were the exponents of this movement.

1. Fact

A fact is a reality, a real state of a thing, which is usually demonstrable. According to Conant, "a fact must be directly observable and must be demonstrable" (cited in Thurber & Collette, 1964). Oxford Advanced Learner's Dictionary defines fact as "something known to be true or accepted as true." A fact can be described as scientific fact only when it has been arrived at using scientific method. The source of information and the method employed in deducing the result should be sufficiently scientific. Facts are the basis of all knowledge. The main function of fact is to initiate, define or redefine new knowledge.

2. Concept

A concept is defined as "an abstraction from observed phenomena; it is a word that states the commonalities among those observed objects or events and distinguishes the phenomena from other objects or events" (Mc Millan & Schumacher, 1989, p. 94). A concept is a generalised mental image, which represents all the members in a particular category. Thus, a concept is a generalised idea built upon several facts. It is a set of specific objects, symbols, or events, which share common characteristics and can be referred by a particular name or symbol.

3. Generalisation

Facts, concepts and generalisations are inter-related and inter-dependent. Facts give rise to concepts and when the facts and concepts are properly classified based on various scientific processes they give rise to generalisations.

4. Principle

A principle is a general statement, which establishes the relationship between at least two concepts. A principle is a statement of relationship, which is significant in its applications. The qualities of a good principle are - - comprehensiveness, logical trueness, verifiability, consistency, etc.

5. Theory

Kerlinger defines theory as "a set of interrelated concepts, definitions and presents a systematic view of phenomena by specifying relations among variables with the purpose of explaining and predicting the phenomena" (cited in Sharma & Shukla, 2002). The qualities of a good theory are:

a. It should be based on related facts, concepts, principles, and generalisations

b. It should be precise and clear

c. It should help in understanding as well as explaining a particular phenomenon or process

d. It should help in interpretation, verification, and prediction

e. It should be grounded on empirical data

Product approach in science teaching

The product oriented approach (also known as traditional) to science teaching makes the assumption that mind is a '*tabula rasa*' or 'blank slate' and the student is a passive receiver of information, an empty vessel waiting to be filled with scientific facts (Driver & Bell, 1986; Cleminson, 1990). Consequently, much of traditional science teaching consists of textbook instruction in which rote memorisation is generally encouraged. It has been well-established that students taught with this approach to science education tend to view scientific knowledge as finite, isolated bit of information (White, 1988; Hewitt, 1990), where many students fail to develop scientific reasoning skills.

Science as a Process

The view of science as a process implies that science is the drawing out of inferences from interaction with experiences. The ways and means adopted by scientists in their pursuit of investigation is the process of science. Science is not a finished enterprise and there remains much to be discovered about the universe. In this aspect, the way of exploring truth is given more emphasis. The method adopted in science in the exploration of truth is unique and distinct from methods adopted by other subjects. The process of science includes the procedures such as observation, collection of data, classification, analysis, synthesis, evaluation and application to new situations.

Process approach in science teaching

The process aspect of science is emphasised in teaching of science which is supported by psychological theories proposed by Piaget (cognitive constructivism), Vygotsky (social constructivism), Gardner (theory of multiple intelligence), etc. The process approach focuses on the learning of inquiry skills more than specific content (Gagne, 1967; Harlen, 1978). This approach encourages the students to generate meaning and knowledge from experience. It considers learners as active participants in the learning process.

Several projects were designed in the teaching of science taking into account the objectives of process approach and anticipating integration of knowledge. Projects such as Nuffield Junior Science in Britain (Harlen, 1978) and courses in Chemistry such as Chemical Education Material Study (CHEM - Study), Chemical Bond Approach (CBA), and Science - A Process Approach (SAPA) of the American Association for the Advancement of Science (AAAS) in the United States are a few along this direction (Pode, 1966; SAPA, 1966). These projects emphasised processes of science such as observing, classifying, inferring and predicting rather than the content of science (Rajan, 2004).

Science as both a Process and a Product

Until recent times science was considered as a collection of knowledge, an area of subject matter, an array of facts, concepts, symbols, equations, and formulae or content. The explosion of knowledge, which influenced all the significant aspects of human activities, penetrated into the field of education also and enriched its content and methods (Joseph, 1982). In the past few decades, there evolved the view that the process and product aspects of science are interdependent and complementary to each other. They are the two sides of the same coin. The product of science can only be arrived at through its processes. The processes of science depend upon the products of science - - it's logical and technical outcomes.

Science as an Attitude

Learning of science helps in bringing a typical change in the attitude of its students. The development of such an attitude is known as scientific attitude. The acquisition of scientific attitude is one of the most important outcomes of learning science. A person with scientific attitude will have the following attributes.

a. Shows disbelief in superstition

b. Records and interprets observations honestly

c. Shows clarity and precision in statements

d. Shows open-mindedness

e. Develops independent thinking

f. Shows spirit of team work, self-help and self-reliance

g. Suspends judgment in the face of insufficient data

h. Shows faith in cause and effect relationship

i. Willingness to consider new ideas and discoveries

The nature of science refers to those characteristics of scientific knowledge that derive directly from how the knowledge is developed. The following characteristics can be attributed to the nature of science (Gega & Peters, 1998):

a. There is no single set or sequence of steps in a scientific investigation

b. Scientific knowledge is subject to change

c. Scientific knowledge must be at least partially supported by empirical evidence (that is, scientific knowledge must involve the collection of data and must be consistent with what we know about the world and be testable)

d. Scientific knowledge is partially the product of the creative imagination of the scientists (that is, all scientific knowledge combines both empirical evidence and the creative interpretation of data by scientists

e. Given the importance of scientists' individual creativity, scientific knowledge is necessarily subjective to some degree (that is, scientific knowledge is not totally objective as is commonly believed)

f. Scientific knowledge is a product of both observation and inference

Place of Science in School Curriculum

Today science has a prime place in school curriculum as a compulsory subject in almost all nations. The reason is simple - - the multifarious values and functions of science to the individual and to the society. The important values/functions of science are discussed below.

1. Intellectual Function

Scientific knowledge helps to develop intellectual honesty among learners. This helps in developing an unbiased attitude towards scientific enterprise. It makes a person systematic, and efficient to face hardships and failures in life. Science does not accept anything, which cannot be proved by actual observation, reasoning, and experimentation. Science helps one to solve problems with sharp intelligence and wisdom. Thus, study of science helps to achieve higher mental faculties such as reasoning, analysis, interpretation, logical thinking, etc.

2. Disciplinary Function

The learning of science develops certain powers of clear and vigorous thinking of coherent and logical deduction, of exact and accurate observation - - a mental discipline characteristic of science. Habits of this kind acquired through science learning will automatically be generalised and transferred to wider concerns of natural life. These qualities are the outcomes of science (Joseph, 1982). Learning of science trains one in scientific method and develops scientific attitude consisting of traits such as open-mindedness, patience, accuracy, cleanliness, punctuality, etc. The mental power acquired by learning science will enable one to discipline oneself and thus help to be a useful member of the society.

3. Utilitarian Function

This is the age of science and technology and the role of science in our daily affairs are innumerable. According to Sir Edward Salisbury, science today has come to play an increasingly important part in our everyday life and an appreciation of its significance, of its findings, of its major trends, of its proper use of appliances are essential to the welfare of individuals in the present and the human race in the future (cited in Nair, 1990). Science has attained a significant role in the different aspects of human life. There is a miraculous change in the ways and means of work and style of life. Science has revolutionised our way of living. It is now essential for everyone not only to understand science but also to manage day-to-day affairs.

4. Recreational Function

Recreation of body and mind is one of the important aspects that need attention in modern life, which is full of tension and frustration. Learning of science can cater to the recreational needs of individuals especially during leisure hours. It develops interests, tastes and appreciations in pupils by offering a large number of opportunities such as hobbies, games and puzzles. Science provides through technology a number of recreational gadgets and facilities such as movies, television, computer, audio-video equipments and musical instruments, which are inevitable and of great recreational value in modern life. Science can create sensitiveness to the beauties of nature and an intellectual appreciation of the great discoveries and inventions of science.

5. Cultural Function

According to the great Indian poet Dinkar, culture is the way of life, which is handed over to society from one generation to another in the form of accumulated customs, habits, and mode of living. The mode and style of living is different from one society to another and therefore their culture is not the same (cited in Mangal, 1990). Culture is the 'way of life' or 'the finer things of life' those we could cultivate through education. The learning of science develops in us a logical mind, a critical judgment, and a capacity for scientific organisation, which is essential for solving the problems in our life. The welfare of our society is dependent upon scientific progress and thus helps the formation of a culture of our own.

6. Vocational Function

Science becomes the primary requirement for a number of vocations and vocational studies. To enter the field of medicine, engineering, agriculture, information technology, etc., the basic criterion is the interest and knowledge of science only. That is why science is considered as an inevitable part of our school curriculum.

7. Aesthetic Function

Science offers a large number of opportunities for the development of refined tastes. Knowledge of science develops in man a passion for truth and beauty in nature. The duty of science is peeping into the mysteries of nature, which is the treasure house of all beautiful things. Thus, teaching of science is essential for developing sensitiveness to the beauty of nature and thereby develops an intellectual appreciation of great discoveries and inventions of science. The difference between a scientist and an artist is that artist aims more deliberately at beauty and a scientist attains and enjoys beauty through reasoning and truth.

8. Social Function

Science is of great value to society from the very beginning. Science has helped a child to become a useful citizen. Today's society stands on pillars of scientific techniques and knowledge. All our social activities depend upon science. Science has provided easy and effective means for transportation and communication, led to increased agricultural and industrial production, sophisticated medical and space research, etc. With these advancements, the society has progressively changed in all dimensions. Thus, science has been functioning as an instrument for social change.

9. Psychological Function

Science learning is based on the fundamental principle of learning by doing and learning by living. It follows the maxims of teaching - - from known to unknown, simple to complex, concrete to abstract, easy to difficult, empirical to rational, specific to general, near to far and part to whole. Knowledge of science helps to satisfy the basic human desire of knowing about wonders of nature and thereby satisfying the instincts such as curiosity, creativity and self-assertion. It also helps in attaining group skills such as co-operation, tolerance, we-feeling, etc., through its manifold activities like hobbies and projects.

10. Provides Training in Scientific Method

Science develops a specific procedure for dealing with problems. Such a method prepares an individual to face the problems of life boldly and to resolve them successfully. The scientific method involves certain thought processes in solving a scientific problem viz., sensing the problem, analysing the problem, testing the validity and accuracy of the various solutions of the problem and application of solutions in similar problems.

Concept of Correlation

Correlation is one of the essential aspect or technique of the modern pedagogical system that makes the study of a subject more purposeful, interesting, permanent and effective by seeking essential coordination and integration with in the different pieces of knowledge along with their application. It is based on the essential notion that knowledge neither exists nor works in isolation (Mangal, 1990). For the sake of convenience, the accumulated fund of knowledge in science is taught under different headings, viz., Chemistry, Physics and Biology. However, all branches of science are inter-dependent and there are a number of facts and principles that are common to these subjects. Therefore, it is not wise to learn science as watertight compartments. The remedy for this is to employ correlation, which means "the reciprocal relationship between various subjects of the curriculum" (Sharma & Shukla, 2002, p. 129).

Correlation is a technique of relating two subjects while teaching any one of them for facilitating meaningful learning and easy understanding of the topic under discussion. We cannot appreciate and understand everything about one branch of science in isolation from others. The correlation of different subjects is very essential for checking artificiality of treatment and for achieving unity of knowledge. One of the most important factors that are responsible for the ineffectiveness of teaching science is the one-sided specialisation. A few argue that without specialisation one cannot possibly understand any one area accurately. However, there is a counter argument that specialisation destroys the natural unity of knowledge. Therefore, it is suggested that teachers of science should have sufficient knowledge of other subjects to bring about integration of different subjects. For example, the functioning of the sense organ eye in biology class is related to image formation by a camera in physics; and while discussing the process of digestion in biology, it is related to chemistry by mentioning the acids involved in the process.

A basic principle of correlation is that the various school subjects must help the learner in a manner to understand his/her environment better. Correlation can be classified in two - - (1) systematic correlation and (2) incidental correlation.

1. Systematic Correlation

Systematic correlation is achieved through planning of the curriculum. This requires group work of a panel of experts from various subjects of study at the time of developing the curriculum. Thorough discussions during curriculum planning can help in avoiding unnecessary repetition of subject matter, as well as help in bringing out good correlation among subjects. Related topics in physics, chemistry, biology and other school subjects can be arranged scientifically for the same standard by proper planning of the curriculum. Systematic correlation will be effective only when the teachers of different subjects co-operate and co-ordinate their work in unison.

2. Incidental Correlation

Contrary to the systematic correlation, incidental correlation is achieved by the planning of the teacher, which is not the result of curriculum organisation. It is intrinsic in nature as the teacher may correlate one topic with another of the same standard or of the previous standard, as and when such a relationship is recalled. The success of such correlation depends on the wide knowledge and resourcefulness of the teacher.

Correlation of Science with Other Subjects

The correlation of science with other subjects is treated under three heads:

(1) correlation of science subjects with one another (2) correlation of science with other school subjects and (3) correlation of science with social and physical environment (Sharma & Sharma, 1971; Kohli, 1986).

1. Correlation of Science Subject with One Another

All branches of science such as physics, chemistry, botany, zoology, physiology, agriculture, geology, etc. are correlated and interdependent upon each other. So science cannot be taught in isolation.

A study of natural science owes much to physics and chemistry. For example, the respiration is related to both physics and chemistry. The change in pressure due to the movement of diaphragm and ribs, resulting in the expansion and contraction of lungs are explained by the principle of physics. Whereas the chemical processes of respiration are explained by chemistry. Similarly, photosynthesis is closely related to physics and chemistry. A biology teacher while teaching the functioning of eye can correlate it with the image formation of convex lens in physics. Again, s/he can mention the use of lenses in the rectification of eye defects such as short-sightedness and long-sightedness. Study of digestive system is interrelated with the chemistry of different digestive juices and their effect on the constituents of food particles. Therefore, it is desirable that the teacher should ensure correlation of different subjects wherever desired in order to improve the effectiveness of teaching learning process. However, when the correlation is made explicit through example, the interdependency will enlighten the leaner to have a better understanding of his/her environment. For this, the teacher should have sufficient knowledge of other subjects.

2. Correlation of Science with other School Subjects

a) Science and language

Science students are usually weak in their expression compared to students in arts and humanities. Science students should be able to express their thoughts in clear, concise, correct and attractive language. Objective type questions minimise the use of language and the value of language is usually neglected. The language teachers frequently demand for the exclusion of science lessons from literature textbooks. These unhealthy outlooks will cause permanent loss to the educational enterprise. Fluency of language is also necessary to express accurately all scientific laws and principles. Language plays an important role in the teaching of science. It is through different languages that people get aware of scientific inventions and are able to appreciate the contributions of science. It is desirable that the language teacher may ask the students to write an essay on some invention or on the life history of a scientist. In addition, pieces of translation can be given from science work. This type of coordination will influence the study of both the subjects in a positive way.

b) Science and social studies

Science and social studies are related to each other to a great extent. The development of science and technology pays a great role in today's high standard of living. Modernisation and industrialisation have revolutionised the outlook and philosophy of life. Many of the scientific principles are directly involved in geographical phenomena.

For example, convection currents, winds, earthquakes, soil, climate and topic such as pressure, temperature, humidity and minerals are common to both science and geography. The construction and use of several instruments such as thermometer, barometer, hygrometer, etc. are common to physical science and geography. The rotation of the planets, change in seasons, flow of ocean currents, structure of earth strata, action of volcanoes and earthquakes are best understood when geology is studied in relation to physical science.

Relation between science and history is very important in topics such as the story of man, the story of earth and the man's endeavours to fight diseases such as leprosy and plague in the East, scurvy and small pox in Europe. History of human civilisation can be divided into different ages on the basis of major sources of power and fuel. The history and science are much more related if we trace the history of discoveries and inventions. In history we see industrialisation as related to scientific inventions.

Science and civics are taught with the same aim of making students good and useful citizens. Science helps the students to understand the utility of scientific inventions enabling them to adjust themselves and to the society. Science helps students to learn, how to dispose of the human waste, the way of leading a healthy life, the way of avoiding infectious diseases and how to render first aid at the time of an accident. All these types of knowledge make them good and dutiful citizens to lead an ideal civic life. In this way both science and civics are interrelated and can be taught in an integrated way (Mangal, 1990).

c) Science and mathematics

The relationship between mathematics and science is highly significant. Science subjects cannot be taught effectively without using mathematics. For example, in the study of topics in physics such as gravitational attraction, the laws of reflection and refraction of light, study of magnetism and electricity, etc., mathematical language and computations are necessary. Similarly, while teaching topics in chemistry such as the laws of combination, structure of atoms, formula of compounds and chemical equations, etc., require basic knowledge of mathematics. Several physical quantities such as density, specific heat, etc., are not measured directly but mathematically calculated from other measured quantities.

The situation is not different in the case of other sciences. Knowledge of mathematics is essential in the study of structure and behaviour of microorganism. Mathematical operations are inevitable in the calculations of Mendel's laws of heredity. In the science of physiology, the human body, structure and its growth are studied accurately in mathematical terms. In the field of medical sciences also mathematics is needed in the accurate measurements of human temperatures, blood pressures, deficiencies of certain substances in human body and the exact composition of medicines required for using certain diseases (Mangal, 1990).

d) Science and craft/drawing

Crafts have several applications in science. Improvisation is an important activity in inculcating scientific thoughts. Crafts such as wood-work, metal-work, cardboard-work, clay-modelling and modelling using plaster-of-Paris can be successfully used in preparing learning aids. Science club activities are closely related to crafts and drawing. Leisure time activities are selected based on students' participation in science club and other activities. Drawing, preparation of charts and some skills in painting will help the study of science subjects. Gramophone records, audiocassettes, film slides, etc., can make science lessons more interesting. Thus the learning of science is related to crafts and drawing.

3. Correlation of Science with Social and Physical Environment

We are living in an age of science; all our activities are controlled and governed by science. The impact of science and technology is evident everywhere. The teachers should correlate their subjects with daily life - - the social and physical environment of the students. Learners should be able to carry over their learning from the physics and chemistry classes to their day-to-day activities. Their life experiences should facilitate the learning of principles of physical science also. For example, while teaching a topic on insecticides or plastics; the teacher can correlate it with the environmental pollution caused by these compounds. While teaching the topic current electricity the teacher can supplement the learning by mentioning the ways and means to save electricity and its importance. It is the duty of science teacher to relate the classroom teaching with the social and physical environments by quoting examples from the daily life of the child.

Advantages of Correlation

The advantages of correlation are enumerated below (Mohan, 2002):

1. **Enhances motivation:** through correlation, the application of a subject in a number of situations can be achieved, and the learner realises the importance of a particular topic or subject and may become interested in learning.
2. **Helps in integration of knowledge:** through correlation, the learner realises the basic unity of knowledge and similarity in the methods of investigation in various subjects. This leads to confidence in the use of the scientific method.
3. **Widens mental horizon:** correlation helps to widen the mental horizon of the learners; for example, a chemistry student becomes familiar with geography, history, and economics, if the study of minerals is properly correlated.
4. **Helps in effective learning:** correlation can lead to more effective learning as the same topic is dealt with in several different situations and viewed from different angles.
5. **Enhances economy of effort:** a topic involving relationship of a number of subjects may be placed under one particular subject and dealt exhaustively, and this reduces the effort in teaching.
6. **Helps in transfer of training:** the learner becomes capable of transferring learning from one situation to other if there is a particular learning common to both. This makes the learning of different subjects more meaningful.

Chapter II

AIMS AND OBJECTIVES OF TEACHING PHYSICAL SCIENCE

Education is the process that brings about pre-determined and desirable changes in the learner. According to Redden, "Education is the deliberate and systematic influence, exerted by the mature person upon the immature through instruction, discipline and harmonious development of physical, intellectual, aesthetic, social and spiritual powers of human being according to individual and social need, directed towards the union of the educand and his creator as the final end" (cited in, Sharma & Sharma, 1971). Every educational aim is an expression of a philosophy of life or a combination of several other competing perspectives about life. The question of what is desirable is determined mainly from five angles. They are:

1. The needs of the society
2. The human stock of knowledge
3. The psychology of learning
4. The philosophy of the nation
5. The nature of the subject matter.

For any sensible activity, there should be clear goals. So in teaching also, a teacher has to base his/her work on the goals set for him/her It is the duty of educators, psychologists, philosophers and national leaders to agree on what is desirable. The role of the teacher is to help to bring about such changes that are desirable. The aims of education are numerous. A few examples of the aims are: knowledge aim, vocational aim, education for character, education for culture, education for leisure, education for citizenship, education for spiritual upliftment, education for individuality, education for social efficiency, education for complete living, etc. These are very broad aims of education.

Importance of Science as a School Subject

Why should science be taught in schools? The aims of teaching science constitute another category which includes eradication of superstitions, improving scientific literacy, better adaptability to new technologies, awareness about health and hygiene, etc. The general education will be incomplete without learning basics of physical science. The impact of science in agriculture, health care, industry, and communication technology are vivid to everyone. Apart from the reasons mentioned above, the important rationale for inclusion of science in the curriculum is that it will acquaint the learner with the process of inquiry.

The inquiry process of science is crucial in training the learner in investigative strategies and in the process by which new knowledge is obtained (National Science Teachers' Association, 1964, pp. 17-19). New scientific techniques can in fact, make-up a deficiency in natural resources and reduce the demands on capital. It is agreed that the national prosperity lies in the effective combination of three factors, viz., technology, materials and capital (Siddiqi & Siddiqi, 1983). Among the three factors, technology is of primary importance and it can grow only out of the study of science and its application. Therefore, Physical Science should form an integral part of school curriculum.

However, aims in general are long term goals which are not realized in a few hours or days. Therefore, in education short term goals are set to measure the changes that are happening in the learner. These short term goals are known as objectives. Educational objectives are "explicit formulations of the ways in which students are expected to be changed by educative process" (Bloom, 1956, p. 26).

Practical, Disciplinary and Recreational Functions of Physics and Chemistry

What knowledge is of most worth? It is hard to give an answer because each discipline provides for our living on this earth. If the learning of science is not of much use in life then it would be waste to spend time teaching it. Learning of physical science helps both the individual and the community. According to the pragmatic school of philosophy, any education must enable the pupil to meet the practical situation in his/her life. The learning environments should promote spirit of community living and principles of democratic living. The practical function of science includes knowledge about the working of household gadgets, modern communication methods, modern methods in agriculture, means of advanced transportation, awareness of health and hygiene, etc. Science education should enable the individual earn a living by preparing him/her for a paying occupation.

It is believed that learning of a subject influences a person in many ways, viz., the ways in which he/she conducts himself/herself in the society, his/her values, his/her thinking and so on. It is believed that Latin develops reasoning power; mathematics develops critical thinking; and science develops willingness to approach situations in an unbiased manner. Exposure to the process of science helps develop skill in observation, search for cause-effect relationship, scientific attitude towards issues and situations, willingness to consider others point of view and so on. The concept of disciplinary value of a subject has roots in mental faculty theory or theory of mental discipline which has certain theoretical pitfall. The details of the theory can be read in any basic book on psychology.

Scientific advancement in the past century and mechanisation tend to reduce working hours. People have more leisure time because of the advancements in transportation and communication. Leisure is free and unoccupied time. However, it should be used to retain general vigour and happiness, and make life rich and prosperous. However, most of the graduates and postgraduates do not have a leisure time activity which they would prefer. The school education should develop tastes which will help the choice of proper forms of recreation. The science education should develop in the learner habits which will give enjoyment during leisure hours. The leisure time can be profitably spent by reading biographies of scientists, collecting pictures of scientists, collecting specimen, preparing toys involving principles of physics, writing articles on topics of interest, etc.

Objectives of Teaching Physical Science

Objectives are specific and immediate goals attainable through instruction. Objectives are defined in fairly concrete terms, the direction in which all educational efforts should move. They are statements which describe the kind of behaviour modification to be brought about in the learner. If objectives are not well-defined, it is impossible to evaluate a course, a unit, a lesson or a student, and there is no sound basis for selecting appropriate materials or instructional methods (Siddiqi & Siddiqi, 1983).

A meaningfully stated objective is one that succeeds in communicating to the reader the writer's (teacher's) instructional intent. Siddiqi and Siddiqi (1983) impose specificity to instructional objectives by stating the conditions and criteria of acceptable performance. For example, given a list of nine levers, the learner must be able to classify them into three orders of lever. The condition in this example is 'given a list of nine levers' and the observable behaviour is to 'classify' the levers. It is desirable to include a criterion of acceptable performance such as 'within ten minutes.'

Several authors have listed ten major instructional objectives of teaching science (e.g., Sharma & Sharma, 1971; Kohli, 1986). They are:

1. Knowledge
2. Understanding
3. Application
4. Skill
5. Interest
6. Attitude
7. Appreciation
8. Training in scientific method

9. Providing work for leisure
10. Providing a basis for vocation

Taradevi Report and Kothari Commission have suggested objectives of teaching science at different levels. These objectives for different school age children are not of much practical value and are not reproduced here.

Objectives describe intended outcomes as a result of properly chosen instructional activities. An objective is a level of mental growth which the learner is expected to reach through learning activities. The learner who has achieved these objectives will be different from the learner who has not. The realisation of an objective brings about certain changes in the behaviour of the pupil. For example, a pupil who has acquired knowledge will be able to recall those items of information and also to recognise them. Here, recall and recognition are two observable and measurable behaviour changes brought about in the pupil as a result of the attainment of the objective, knowledge. The objectives by themselves are not directly observable and measurable, but evidences of their attainment can be collected through specifications or learning outcomes. These observable and measurable behavioural changes are the specification of that objective.

Tyler (1949) suggested that "the most useful form for stating objectives is to express them in terms which identify both **the kind of behaviour** to be developed in the student and **the content or area of life** in which this behaviour is to operate" (p. 30). The objectives should be stated in terms of changes expected in the learner rather than as duties of the teacher. The terminology should be unambiguous and each statement should refer to one objective only. There shall be two parts to each statement of the objective, one pertaining to the mental process and the other to the content area.

Taxonomy of Educational Objectives

Taxonomy is a science of classification of things or ideas. The term taxonomy is derived from two Greek words '*taxis*' (meaning arrangement) and '*nomos*' (meaning law). Thus, taxonomy is the law of systematic arrangement. Taxonomy is an educational-logical-psychological classification system in which every term should be defined precisely (Siddiqi & Siddiqi, 1983). Any law of systematic arrangement involves hierarchies. In a hierarchy, ideas are arranged into different levels of importance. The initiative in developing taxonomy of educational objectives gathered momentum in 1948 in the convention of the American Psychological Association held in Boston. The participants expressed their interest in developing a theoretical framework, which could be used to facilitate communication among examiners. During 1948-53, several meetings were held to develop a taxonomy, which resulted in the most influential book, "Taxonomy of Educational Objectives," edited by Benjamin S. Bloom in 1956.

The purpose of taxonomy is to set a standard for classification whereby terms used in the classification are defined precisely. According to Bloom's Taxonomy, behavioural changes of individuals resulting from instruction can be classified into three domains. They are - - (1) Cognitive Domain, (2) Affective Domain, and (3) Psychomotor Domain. The details of each domain are given below.

I. Cognitive Domain (Knowing)

The term 'cognitive' is used to include activities such as remembering and recalling knowledge, thinking, problem-solving and creating. The cognitive domain includes those objectives which deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. Knowledge is considered basic to all other ends or purposes of education. Knowledge involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting. The knowledge objectives emphasize most of the psychological processes of remembering. An objective is the intended behaviour of students – the ways in which individuals are to act, think or feel as result of participating in some unit of instruction. The formulations of educational objectives depend on - - (1) previous experience of teacher, (2) our understanding about the learner, and (3) the nature of the subject matter. Accordingly, following objectives were formulated under the cognitive domain.

1.00 Knowledge

Knowledge, as defined here, involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting.

1.10 Knowledge of specifics: This involves recall of specific and isolable bits of information.

1.11 Knowledge of terminology – This involves knowledge of referents for specific symbols (verbal and non-verbal). For example, Calorie.

1.12 Knowledge of specific facts – This involves knowledge of dates, events, persons, places, etc,. For example, the atomic number of Sodium is 11.

1.20 Knowledge of ways and means of dealing with specifics: This involves the knowledge of the ways of organising, studying, judging, and criticising.

1.21 Knowledge of conventions – This involves knowledge of characteristic ways of treating and presenting ideas and phenomena. For example, the magnetic poles of a magnet are named north and south.

1.22 Knowledge of trends and sequences – This involves knowledge of the processes, directions and movement of phenomena with respect to time. For example, the sequence of the evolution of the structure of atom since 1805.

1.23 Knowledge of classifications and categories – This involves knowledge of the classes, sets, division, and arrangements which are regarded as fundamental for a given subject field, purpose, argument or problem. For example, burning of oil is classified as a chemical change

1.24 Knowledge of criteria - This involves knowledge of criteria by which facts, principles, opinions, and conduct are tested or judged. For example, the criteria for classifying an element as a transition element.

1.25 Knowledge of methodology – This involves the knowledge of methods of enquiry, techniques, and procedures employed in investigating particular problems and phenomena. For example, the procedure of salt analysis.

1.30 Knowledge of the universals and abstractions in a field: This involves the knowledge of the major schemes and patterns by which phenomena and ideas are organised.

1.31 Knowledge of principles and generalisations – This involves knowledge of particular abstractions which summarise observations of phenomena. For example, if the volume of a given mass of gas is kept constant, the pressure will decrease by reducing the temperature.

1.32 Knowledge of theories and structures – This involves knowledge of the body of principles and generalisations together with their interrelations which present a clear, rounded, and systematic view of complex phenomenon, problem, or field. For example, the structure of atom.

2.00 Comprehension

This represents the lowest level of understanding.

2.10 Translation: Comprehension as evidenced by the care and accuracy with which the communication is paraphrased or rendered from one language or form of communication to another. In this objective skill in translating mathematical verbal material into symbolic statements such as the Pressure is inversely proportional to Volume at constant temperature can be translated into the mathematical form.

2.20 Interpretation: The explanation or summarisation of a communication. This involves reordering, rearrangement, or a new view of the material. An explanation for - - "Why the life of an electric bulb is 1000 hours?"

2.30 Extrapolation: This involves the extension of trends or tendencies beyond the given data to determine implications, consequences, corollaries, effects, etc. In other words, it is the skill of predicting continuation of trends. Given the graphical representation of solubility of salt with temperature, the solubility at a temperature beyond the range can be inferred by extrapolating the graph.

3.00 Application

Application involves the use of general ideas, rules of procedure, or generalised methods in particular and concrete situations. For example, what is the principle involved in the working of a fan regulator?

4.00 Analysis

The breaking down of a communication, phenomenon or idea into its constituent elements or parts. For example, analysis of a salt into acid and basic radical those constitute the salt.

4.10 Analysis of elements: For example, analysis of a compound into its constituent elements.

4.20 Analysis of relationships: For example, analysis of the relationship between concentration of a reactant and the rate of a reaction.

4.30 Analysis of organisational principles: For example, how will you classify organic compounds?

5.00 Synthesis

This involves putting together of elements and parts so as to form a whole. That is, arranging and combining pieces, parts, elements, etc., in such a way as to constitute a pattern or structure not clearly there before.

5.10 Production of unique communication

5.20 Production of a plan, or proposed set of operations

5.30 Derivation of a set of abstract relations

6.00 Evaluation

This involves judgments about the value of materials and method for given purposes.

6.10 Judgments in terms of internal evidence such as logical accuracy, consistency, and other internal criteria.

6.20 Judgment in terms of external criteria such as major theories, generalisations, and facts about particular cultures.

II. Affective Domain (Feeling)

Objectives of affective domain emphasise emotions or a degree of acceptance or rejection of information (facts, concept, etc.). The affective domain relates to the learners' emotional expression regarding what is acquired. It is a fact that instructional objectives in the affective domain is hard to achieve and manipulate. These objectives are rarely measured in the regular classroom-testing environment. The affective domain will include attitude, appreciation, interest, emotional and social adjustments. The hierarchical growth of affective domain and objectives are listed below.

1. Receiving

The learner is sensitised to the existence of a particular stimulus (a fact, a phenomenon), that is, s/he is willing to receive or attend to the stimulus. This is evidently the first and the crucial step if the learner is to be properly oriented to learn what the teacher intends to teach. This category is further divided into three sub categories - - awareness, willingness to respond, controlled or selected attention

2. Responding

At this level the learner goes beyond merely attending to the phenomenon. S/he desires to become sufficiently involved in or committed to a subject, phenomenon, or activity that s/he will seek it out and gain satisfaction from working with or engaging in it. The sub categories of the objective are - - acquaintance in responding, willingness to respond, and satisfaction in response.

3. Valuing

This is concerned with individual's own valuing or assessment, but it is much more a social product that has been slowly internalised or accepted. This category will be found appropriate for many objectives that use the tem attitude, as well as value. An important element of behaviour characterised by valuing is that it is not motivated by the desire to comply or obey, but by the individual's commitment to the underlying valued guiding the behaviour. The sub categories of this objective are - - acceptance of value, performance of a value, and commitment.

4. Organising

The learner successively internalised values and encounters new situations which demand more than one value. Thus, necessity arises for the organisation of values into a system, the determination of interrelationships among them and the establishment of the dominant and pervasive ones. The system thus formed will gradually change incorporating new values. This will involve conceptualisation of value and organisation of a value system.

5. Characterising

At this level of internalisation, the learner will have a value hierarchy and an internally consistent system of values that control the behaviour of the individual. The individual acts consistently in accordance with the values s/he has internalised. This result in a general pattern of behaviour which is the result of integration of different beliefs, ideas and attitudes or a philosophy of his/her own. The sub categories of this objective are - - generalised set and characterisation.

III. Psychomotor Domain (Doing)

The psychomotor domain will presumable contain different types of small and large muscular skills involved in physical learning, surgery, vocational education of various mechanical and clerical trades. The hierarchical growth and objective of psychomotor domain are given below.

1. Manipulation

Manipulation involves working with hands or tools to operate a mechanical device or any such system which require various movements of small and large muscles. The sub categories of this objective are - - following direction, selection and fixation.

2. Control

Control involves skill in operating and regulating an experimental set up or a device. It will include accuracy, proportion and exactness in performance. Precision in titration is achieved by skilled use of pipette and burette.

3. Co-ordination

Co-ordination involves harmonious integration of different skills at proper sequence. The combination of skills will require a particular speed in movements which at the same time follow a particular pattern.

4. Naturalisation

Naturalisation implies that pupil's skill attains its highest level of proficiency, that is, the act becomes automatic. For example, when driving a car, suppose break is applied, then the automatic act is to press the clutch pedal to shift the gear to a lower speed.

It may be noted that even though an objective is classified under one domain, it is not entirely devoid of components from other two domains. Thus, educational objectives are the changes in specific terms that the teacher wishes to produce in the learner in the areas of knowing, feeling and doing. Dave has suggested five objectives for the psychomotor domain, viz., **imitation, manipulation, precision, articulation** and **naturalisation** (cited in Mohan, 2002).

The fifteen objectives under the three domains given above are reclassified into seven for practical purposes of lesson planning by the National Council for Educational Research and Training (NCERT) as early as 1973. In this classification the objective application includes analysis, synthesis and evaluation of the cognitive domain. (This was also a criticism against the hierarchy of the classification of the cognitive domain. That is, application will not be possible without analysis, synthesis and evaluation and the hierarchy is questionable). The five objectives under affective domain are reclassified into three with different terms, viz., interest, attitude and appreciation. The four objectives of psychomotor domain are represented by a single objective skill. Thus the seven instructional objectives are:

1. Acquiring knowledge
2. Developing understanding
3. Developing application
4. Developing skills
5. Developing interests
6. Developing attitudes
7. Developing appreciation

Bloom's (1956) classification dominated educational planning for about half-a-century. Mc Cormack and Yager (1989) proposed a **new taxonomy of science education** with five domains. These domains are - - (1) Knowledge Domain, (2) Process Domain, (3) Creativity Domain, (4) Attitudinal Domain and (5) Application Domain. The five domains and important processes and skills associated with each domain are given below.

1. Knowledge Domain (Knowing and Understanding)

This domain includes knowledge and understanding. Knowledge acquired in real-life situations are more meaningful and are retained in the memory. This domain deals with all the content areas that are directly dealt in the textbook. They are - - symbols, terms, facts, concepts, formulae, equation, laws, principles, and theories.

2. Process Domain (Exploring and Discovering)

This domain focuses on knowing how scientists develop new knowledge and helps to internalize the method of science and to instil an interest in conducting scientific enquiries. Science A Process Approach (SAPA) of the American Association of Advancement of Science (AAAS) in the early 1960s de-emphasised 'content' and focused on the 'process of knowing.' Subsequently, a list of specifications was formulated in 1965 (cited in, Bhatt, 1988). Those thirteen process skills and objectives suggested in the new taxonomy under the process domain are the same. They are:

i. Observes: Beginning with identifying objects and object properties, proceeds to the identification of changes in various physical systems, the making of controlled observation, and the ordering of series of observation.

ii. Classifies: Development begins with simple classifications of various physical systems and progresses through multistage classification, their coding and tabulation.

iii. Uses Numbers: This sequence begins with identifying sets and their members, and progresses through ordering, counting, adding, multiplying, dividing, finding average, using decimals and

iv. Measures: Beginning with the identification and ordering of lengths, development in this process proceeds with the demonstration of rules of measurement of length, area, volume, weight, temperature, force, speed, and a number of derived measures applicable to specific physical and chemical systems.

V. Uses space-time relationships: This sequence begins with the identification of shapes, movement and direction. It continues with the learning of rules applicable to straight and curved paths, direction at an angle, changes in position, determination of linear and angular speeds.

vi. Communicates: The learner must develop the ability to convey acquired knowledge through diverse means. Different social form of discourse such as debate and seminar can be utilized in communication. It will include description of simple phenomena and explanation of observed results of experiments.

vii. Predicts: What happens to a chemical system at equilibrium involving gases if Pressure is increased? This process involves interpolation and extrapolation of data to the formulation of methods of testing predictions.

viii. Infers: Initially the idea is developed that inferences differ from observations. As development proceeds, inferences are constructed for observations of physical and chemical phenomena, and situations are constructed to test inferences drawn from hypotheses.

ix. Develops operational definitions: Beginning with the distinction between definitions which are operational and those which are not, this developmental sequence proceeds to the point where the child constructs operational definitions in problems that are new to him/her.

x. Formulates hypothesis: At the start of this sequence, the child distinguishes hypotheses from inferences, observations, and predictions. Development is continued to be stage of constructing hypotheses and demonstrating tests of hypotheses.

xi. Interprets data: This sequence begins with descriptions of data and inferences based upon them, and progresses to constructing equations to represent data relating to statements of hypotheses, and making generalizations supported by experimental findings.

xii. Controls variables: The developmental sequence for this "integrated" process begins with identification of manipulated and responding (independent and dependent) variables in a description of demonstration of an experiment. Development proceeds to the level at which the students, being given a problem, inference, or hypothesis, actually conducts an experiment, identifying the variables, and describing how variables are controlled.

xiii. Experiments: This is the capstone of the "integrated" processes. It is developed through a continuation of the sequence of controlling variables, and includes the interpretation of accounts of scientific experiments, as well as the activities of stating problems, constructing hypotheses, and carrying out experimental procedure.

3. Creativity Domain (Imaging and Creating)

Important skills under this domain are:

i. Combines objects and ideas in new ways.

ii Predicts alternate or novel uses of objects.

iii. Solves problems and puzzles.

iv. Visualises - producing mental images

v. Designs devices and machines

vi. Advances unique ideas

vii. Lateral thinking - This is a method of solving problems using concepts and thoughts which are different from the usual one's

viii. Fantasying

ix. Dreams about possibilities

4. Attitudinal Domain (Feeling and Valuing)

An important aim of science education is to develop scientific attitude and values. Important components of this domain are:

i. Develops positive attitudes towards science and teachers of science.

ii. Expresses personal feelings in a constructive way.

iii. Takes decisions about personal values.

iv. Makes decisions about social and environmental issues.

v. Develops sensitivity to and respect for the feelings of other people.

5. Application Domain (Using and Applying)

Important components of this domain are:

i. Locates technological principles involved in house-hold devices

ii. Applies science concepts and skills to everyday technological problems

iii. Selects relevant scientific processes in solving problems of everyday life

iv. Relates scientific concepts to life experiences

v. Makes decisions based on knowledge of science

vi. Integrates science with other subjects

vii. Evaluates mass media reports on scientific developments

The popular taxonomy of educational objectives known as Bloom's taxonomy was revised mainly for two reasons (Anderson & Krathwohl, 2000). That is, (1) to refocus educator's attention to the value of the original handbook and (2) to incorporate new knowledge about how children develop and learn and how teachers plan to teach and assess their students. This taxonomy is organised around four basic questions - - (1) What is important for students to learn in the limited school and classroom time available? (2) How does one plan and deliver instruction that will result in high levels of learning for a large number of students? (3) How does one select or design assessment instruments and procedures that provide accurate information about how well students are learning? (4) How does one ensure that objectives, instruction, and assessment are consistent with one another?

In the revised taxonomy, knowledge is classified into factual, conceptual, procedural and metacognitive. The factual knowledge is isolated bits of information such as knowledge of terminology whereas conceptual knowledge is knowledge of more organised knowledge forms such as generalisations, categories, principles, theories and structures. Procedural knowledge is knowledge of 'how to do something'. This includes techniques, methods and criteria used within specific disciplines. Metacognitive knowledge is knowledge about cognition. It includes knowledge about cognitive tasks, strategic knowledge and self-knowledge. The six cognitive process categories of the revised taxonomy are given below.

1. Remember

This involves retrieving relevant knowledge from long term memory.

The two cognitive processes are recognising and recalling

1.1 Recognising

1.2 Recalling

2. Understand

This involves making connections between the "new" knowledge to be gained and their prior knowledge. The new knowledge is integrated with the existing shema and cognitive framework. The cognitive processes of this category are given below.

2.1 Interpreting

2.2 Exemplifying

2.3 Classifying

2.4 Summarising

2.5 Inferring

2.6 Comparing

2.7 Explaining

3. Apply

This involves using procedures to perform exercises or solve problems. This is closely linked with procedural knowledge. The cognitive processes of this category are given below.

3.1 Executing

3.2 Implementing

4. Analyse

This involves breaking material into constituent parts and determining how the parts are related to one another and to an overall structure. The cognitive processes of this category are given below.

4.1 Differentiating

4.2 Organising

4.3 Attributing

5. Evaluate

This involves making judgments based on criteria and standard. The cognitive processes of this category are given below.

5.1 Checking

5.2 Critiquing

6. Create

This involves putting elements together to form a coherent or functional whole. The cognitive processes of this category are given below.

6.1 Generating

6.2 Planning

6.3 Producing

There are several other classifications of educational objectives relevant to different disciplines. Our understanding of the process of learning is emerging and therefore, change is imperative. A willingness to accept or acknowledge these possibilities is a good step in the right direction to improve teaching-learning processes.

Chapter III

CURRICULUM DEVELOPMENT

The term curriculum comes from the Latin word '*currere*' which means to run. The Latin root of the word 'curriculum' means race course. The course of race, with time came to mean the "course of study" (Wiles & Bondi, 1989, p. 6). Thus, curriculum is a run way, a course, which one runs to reach a certain goal.

Several definitions of curriculum stem from differences in educator's philosophy and how they envision the school/college programme. The accountability movement in education has pushed the definition of curriculum towards an emphasis on the outcome of education. For example, curriculum is defined as, "the planned and guided learning experiences and intended learning outcomes formulated through systematic reconstruction of knowledge and experience, under the auspices of the school, for the learner's continuous and wilful growth in personal-social competence" (Tanner & Tanner, 1975, p. 45).

There are other definitions of curriculum which use analogies to convey the meaning of curriculum. For example, Cunningham defined curriculum as, "the tool in the hands of an artist (the teacher) to mould his material (the pupil) according to his ideals (aim and objectives) in his studio (classroom/school)." The idealistic philosophy underlying the above definition is evident from the role of teacher assumed in the process of education. The point is that the meaning attached to the word curriculum reflects educator's philosophy and other biases.

Decisions about curriculum emerge from complex interactions among several factors such as educational philosophy, educational psychology, political philosophy of the nation, social needs and the like (Mitzel, 1982). These factors operate at different levels of decision making, viz., ideological, societal, institutional and instructional. The dynamics of decision-making process of Physical Science Study Committee (PSSC) tells us the biases and prejudices of the curriculum committee members (Rajan, 2006).

The above discussion about decision making process is to alert the reader to the fact that there are no definite prescriptions regarding curriculum development. However, there are general principles that may help in selecting curriculum for any course of study which are detailed below.

General Principles of Curriculum Development

The basic principles of curriculum development are given below.

1. Principle of Utility

Aristotle (384-322 B.C.) stated that children should be taught those useful things really necessary in life. Such a utilitarian consideration can be seen in any curriculum. The curriculum must include speaking, reading and writing one's language, simple arithmetic and measurement, physical education and care of health and some craft.

2. Principle of Development of Innate Powers

Subjects of study were selected mainly on the basis of their value in disciplining certain mental powers, as decided by their form. The development of innate faculties depends on the content and method of learning. Activities calling for unfolding of the different powers should be included in the curriculum.

3. Principle of Adjustment to one's Environment

Rusk analyses man's environment into two - - material (physical) and cultural (spiritual). The latter has been classified into three - - intellectual, aesthetic and moral. The curriculum must represent all these.

4. Principle of Exaltation of Human Personality

Education is seeking to exalt human personality by adjusting the individual to his/her cultural environment. This is the view of idealists. They want the individual to accept, and strive for the values - - truth, beauty and goodness. This is to be done by recapitulating the life of the race and so the curriculum should be an epitome of race experience.

5. Principle of Relevance to Present Life

All experiences are educative. However, only those experiences of the race which have relevance in helping the individual to understand the present and adjust himself/herself to his/her needs be included in the curriculum.

6. Principle of Conservation of Culture

Percy Nunn puts this as special function of nation's schools. Education should seek to conserve the best and most valuable experiences and achievement of the race, by transmitting them to the succeeding generations. Therefore, curriculum should include all the creative activities that help safeguard the conditions of the individual and social life.

7. Principle of Progress

The curriculum should culminate in the continuous expansion and refinement of knowledge. Therefore, the nation's schools should be agents in the process of modernisation and progress. Hence, curriculum should include science, crafts, social manners, etc.

8. Principle of Vocational Requirements and Aptitudes

The curriculum should cover the requirements especially the fields of specialisation. Vocational training in line with the special aptitudes of pupils is desirable.

9. Principle of Leisure

Education must prepare persons not only for the serious business of life but also for leisure. Hence, the curriculum must include cultural pursuits and hobbies which will provide for recreation and enjoyment.

10. Principle of Need and Interests of Pupil

The growing problems of life are in a way an important factor which should determine our present curriculum so that the learner can tackle them profitably in a personally satisfying and socially acceptable manner. The needs and interests of the learner are even more important factors for which the curriculum should give due importance.

11. Principle of Variety and Flexibility

The materials and activities should have rich variety to prevent boredom. The major defect of the present day curriculum is its stereotyped treatment which kills novelty. The curriculum should be adaptable to the individual needs and local conditions.

12. Principle of Activity

Friedrich Froebel (1783-1852) considered self-activity as the method and process of development. Self-activity arises out of one's own interests. Self-activity, in his opinion, is a process by which the individual realises his own nature. Since the child is free to determine his/her own activities, the instruction requires no artificial techniques. The curriculum must have scope for varied and interesting activities. The concepts of "gifts" and "occupations" are designed to stimulate activity (Purkait, 1995, p. 193).

There are several other criteria such as preparation for life, educational value of subjects, and balance among different subjects, correlation, richness and broadness, length of course and suitability which is also important in making decisions about curriculum.

Defects of Traditional Curriculum

The traditional curriculum has a focus on the disciplining value of subjects. That is, the curriculum was content-centered. Also the teacher was considered as a "matured" person with necessary knowledge and understanding of what is desirable for a student. The student was considered as the immature who is to be "matured" through education, the control of which rests with the teacher. Thus, it was teacher-centered. Jean Jacques Rousseau (1712-1778), Friedrich Froebel (1783 - 1852), and Johann Heinrich Pestalozzi (1746 - 1827) argued for a child-centered education. The rationale of their proposition was compelling to shift from the traditional ways (content-centered and teacher-centered) to a child-centered approach. Later, Herbert Spencer (1820 - 1903) and John Dewey (1859 - 1952) influenced the child-centered education with due weightage to a life-centered scheme (see, Purkait, 1995; Ozmon & Craver, 1986). The defects of traditional curriculum are listed below.

I. Bookish and theoretical,

2. Over-loaded with factual knowledge.

3. Little provision for physical, intellectual, social, and other practical activities.

4. No adequate provision for needs of the different stages of development.

5. Not much provision for individual difference - interest, aptitude, etc.

6. Not easily adaptable to local conditions.

7. Not much vocational and technical provision.

8. Does not provide for work experience and community living.

A Logic of the Physical Science Curriculum

The general principles of curriculum construction and common defects of traditional curriculum are equally relevant to physical science. However, as stated earlier decision about curriculum neither result from empirically verifiable generalisation nor from any experimental finding (Kliebard, 1977). Curricularists will have to decide among competing choices (Kliebard, 1982) while being aware of a multitude of factors and possible interactions among those factors. The available literature, identifies two models of curriculum development - - (1) prepared in 1932 by the National Society for Study of Education (cited in Osborn, 1960) and (2) the Tyler model (Tyler, 1949).

The National Society for Study of Education suggested three basic factors in the curriculum development, viz., a subject matter specialist, a classroom teacher or supervisor and a specialist in science teaching.

This model is limited to the instructional element of curriculum and does not account for the psychology of the learner and the needs of society. Tyler is more comprehensive in his approach and suggests that there are three principal sources to be considered in curriculum construction, viz; studies of learners (psychological), studies of contemporary life (sociological) and suggestions from subject specialist (structure of knowledge). He suggests that needs and interests of the three sources should be filtered through a philosophical mesh to get the final curriculum. Tyler gives an upper hand to philosophy, whereby the other parameters are diminished. It is important to look at physical science curriculum in the background of what is outlined above. Any curriculum when put in the frame described above help to see the dominance of one source over the other.

Paul Hirst observed that anyone who advocates curriculum changes on pure philosophical grounds without considering the psychological and sociological factors that are relevant is simply irresponsible (Hirst, 1971, p. 232). Therefore, added to subject specialists, it is fundamental that any curriculum construction (more appropriately, curriculum development) effort must have participation from the three groups philosophers, psychologists and sociologists. The details of each of this area are summarised in the following paragraphs.

A Philosophy of Science Curriculum

The popular schools of philosophy that are included in the graduate programme of education are - - (1) Idealism, (2) Naturalism, (3) Pragmatism and (4) Realism. The basic elements of these schools of philosophy with respect to aims of education, content, and role of teacher, method of instruction and concept of discipline are different. These educational philosophies and the differences among them are enumerated by several authors (e.g., Ozmon & Craver, 1986). A philosophy of science education alone will be dealt in this section.

A philosophy of science curriculum can evolve only from an understanding of the nature of science. As described earlier, science is now considered both a product and a process. Inquiry skills and scientific methods of inquiry are supposed to reflect the nature of science as a process. There are several false dichotomies such as product or process. The dichotomy is a distortion of the nature of science (Robinson, 1968) for the process of knowing is inseparable from what is known. The process of knowing and the knowledge used in the process of knowing are equally important. To substantiate, Sir Issac Newton once testified, "If I have seen farther than Descartes, it is by standing on the shoulders of giants" (Wilson, 1937). According to Losee, the philosophy of science is concerned with four basic questions (cited in Hodson, 1985, p. 31).

They are:

1. What characteristics distinguish scientific inquiry from other types of investigation?
2. What procedures should scientists follow in investigating nature?
3. What conditions must be satisfied for a scientific explanation to be correct?
4. What is the cognitive status of scientific laws and principles?

   Several authors on curriculum development agree on these points (see, Hodson. 1985, 1986).

Psychological Dimensions of Physical Science Curriculum

Several psychological theories provide insight in developing physical science curriculum. Mental faculty theory, theories about transfer of training theories about the process of learning and developmental theories are all illuminating our understanding of the various psychological dimensions of physical science curriculum.

According to the mental faculty theory or faculty psychology mind consists of certain independent faculties such as attention, memory, imagination, reasoning, etc. Faculty physiologists believed that as exercising of muscles results in improvement, training improves mental faculties. For example, it was believed that Latin develops reasoning power; mathematics develops attention, science develops critical thinking, physical education develops will power and so on. However, the theory of mind as water-tight compartments is no longer considered valid.

John Locke (1632 - 1704), a famous British philosopher, held the view that mind is a "*tabula rasa*" or "blank slate". That is, the mind is a clean slate without anything marked on it. This conception of child's mind as a blank slate assumes that the child (student) is a passive consumer of information, an empty vessel waiting to be filled with scientific facts (Popper, 1972).

Beginning of 20th century (with the efforts of Alfred Binet) witnessed a large scale testing of intelligence (Feder, 1979). A critical study of the intelligence tests resulted in a shift in emphasis from the use of intelligence tests to the measurement of special aptitudes (Anastasi & Foley, 1953). Third quarter of the 20th century noticed another trend which is identified in education literature as "Aptitude Treatment Interaction" (ATl). That is, aptitude of individual functions selectively with respect to learning under different instructional treatment (Cronbach & Snow, 1977). In other words, one instructional treatment (method) is significantly better for one type of student while an alternate treatment is significantly better for a different type of student. Thus, there is no method that has a universal applicability. Different individuals thrive in different environments suited to their own characteristics and needs (Koran & Koran, 1984).

The transfer of training and theories thereof (identical elements and generalisation) are important in the organisation of curriculum. Individualised instructional techniques, programmed learning mate-rials are all focusing on the individual difference. The learning theories and laws of learning find more application in the instructional techniques rather than in curriculum development. The contri-butions of Piaget, Gagne, Bruner and Ausubel provide us with logic as to what a student can learn in two counts - - (a) the developmental stage and (b) the pre-requisites. The details are given elsewhere in this book.

The last quarter of the 20th century is extending the "constructivist" view of the learner proposed by Piaget to a generative learning model (Osborne & Wittrock, 1983). The generative learning model is that the child's brain is much more than a blank slate and in that it ignores some information and, selectively attends to some other information. Several researchers have investigated students' pre-instructional understanding of certain concepts (e.g., Saxena, 1994). As Linn (1986) suggested, there is an emerging "science of science teaching" based on the proliferation of knowledge in the psychology of learning science that could make curriculum reform dramatic.

There are several maxims about the teaching-learning process. A few of them are: known to unknown, concrete to abstract, simple to complex, easy to difficult, empirical to rational, specific to general, definite to indefinite, part to whole, near to far and so on. These maxims have roots in some psychological principles.

Sociological Principles of Curriculum Development

The structure and function of a society has its reflections in curriculum. For example, a rural and backward country and an industrially developed country will have to adopt different types of curriculum. The UNESCO has drafted curriculum for the developed, developing and the under developed countries. In India, education has to be used for social change and development. Hence, a curriculum for India should take into consideration the poverty and superstition of the masses that live in isolation in villages and set the background for social change.

Social changes are changes in attitudes, behaviours, manners, relations, customs, habits, etc. Education is expected to change the values and attitudes of the people and to create in them the urge or motivation to achieve social class ascendancy or social mobility. The curriculum must also function as a means to enhance agricultural productivity, better health and sanitation awareness among our citizens.

Recently, a major thrust in curriculum revision is to interface industries with colleges and universities. More specifically, the Research and Development (R & D) divisions of industries collaborate with the respective departments in colleges and universities so as to connect the science education with the society. The infra-structure facilities of both industries and educational institutions can be profitably exploited for the common good of the society. One of the major functions of higher education, as identified by the University Education Commission is the "extension" which will become more viable in this collaborative enterprise.

Organising Science Curriculum

The basic requirement of any organisational scheme or plan is that it should maximise the total effect of selected learning sequences. The learning sequence follows some basic dictum such known to unknown, concrete to abstract, simple to complex, empirical to rational, specific to general, part to whole, near to far and so on.

In the organisation of a subject, it has been pointed out that any subject can be logically organized in a number of ways. Failure to recognise the implications of this has led to the opposition of the 'logical' order of subject matter and the psychological order of learning experiences. This opposition stems from an undue emphasis on learning considered as product rather than as process and from a failure to discriminate between subject matter and the experiences through which it is learned. The problem presented is a pseudo-problem, because there is no such thing as the logical organisation of a subject. How a subject is organised depends on the purposes which the organisation is to serve, and the test of the goodness or badness of the organisational scheme is the total effect of the extent to which it helps to bring about the desired ends. Because of historical facts, exposition and the deductive mode of thought have had the greatest authority in schools.

Many of the objections to the subjects as general organizing categories arise from the methods of teaching rather than from the organisational pattern. So, attempts at new organisations have been by way of the introduction of problem-solving methods and inductive processes. What is, in effect, a complaint about the methodology of the teaching-learning process has been taken as an objection to one sort of organisation. Like some of the other dichotomies mentioned, the 'logical-psychological' controversy arises from undue emphasis on one or the other of the two interrelated things, the content and learning experiences (Wheeler, 1967).

The selection of the content usually comes from a particular syllabus which has been developed by the State Council for Educational Research and Training (S.C.E.R.T.). Unfortunately, most of the science teachers are not directly involved in the construction and organisation of a complete curriculum. Hence, it is recommended that whenever possible the classroom science teacher should play a vital role in the development and organisation of science programme which s/he is expected to follow.

Suggestions for Organising Science Curriculum

Science teachers should regularly meet with supervisors, consultants and teachers from other schools to plan and formulate objectives. A possible danger is that a science curriculum which is organized by others cannot be accepted with as much enthusiasm and understanding as when the science teacher is an active participant. The natural curiosity of boys and girls should be considered throughout the sequence of learning activities. To stimulate curiosity high school teacher must prepare demonstrations and experiments appropriate for each topic (unit). The approach not only fosters pupils' curiosity but also leads to problem-solving or other creative activities on the part of the learner. Science teachers should organize materials so as to develop scientific attitudes and skills in scientific discovery, through an emphasis on inductive and deductive reasoning. Students acquire scientific attitudes, suspend judgments and avoid hasty conclusions in addition to mastering of laboratory skills of designing experiments to test hypothesis.

Science curriculum is organised to include up-to-date references, resource materials and resource persons from the community and allow the needed flexibility to bring in contemporary discoveries. Values and appreciation are influenced by selected readings from history, biography and philosophy of science. In many communities a mechanical engineer, biochemist, local health officer and other scientific personnel can make worthy contribution to strengthen the science programme. Publications such as *Eureka, Shasthragathy, Shasthra Keralam, Current Science, Chemistry, Popular Mechanics, Popular Science, Science* & *Mathematics weekly, Science New's Letter, Scientific American and Science world* should be used in organising a science cuirriculum. Books dealing with philosophy of science, history of science and lives of great scientist should also be made use of. Students should also be encouraged to build a home-library containing many of these materials.

Pupil-teacher planning and pre-planning can be a very strong influence in the improvement of curriculum organisation. The science teacher learns much about science and the students when pupils participate with teacher in curriculum planning. Individual student as well as group of students proposes projects that are used for the school museum or the science fair. Individual student perform demonstrations that they have shown interest in bringing to the attention of the class. The organisation or a science curriculum should enable teachers to substitute new ideas for outdated ones and to augment and supplement current and scientific information. Flexibility becomes the factor for maintaining up-to-date science programme.

General Approaches in Curriculum Organisation

There are four alternatives in curriculum organisation each of which is identifiable in the pattern of curriculum organisation. They are:

(1) Movement down a long road

(2) The swing of a pendulum

(3) The upward and spiral (Miel, 1971) and

(4) Historical approach. Each of the patterns is detailed below.

1. Movement down a long road

One view of curriculum organisation is that it is like movement down a long road whereby arrangements or practices once considered adequate are left behind forever. All that is abandoned becomes the traditional. The new which is at hand is the right way

or the modern. A shift from broad fields curriculum to subject matter curriculum and then to activity curriculum adequately de-scribes the movement down a long road pattern. This view reflects the either or type of thinking so difficult to avoid in human affairs.

We move from one emphasis to another with no return for a second look (Miel, 1971). Another example of the type will be special schools for the physically challenged (differentially abled) students to mainstreaming.

2. The Swing of a Pendulum

The second way of looking at the curriculum organisation is to draw an analogy to the swing of a pendulum back and forth in the same groove. According to this view the weight of opinion may go from teacher-centered method to a child-centered method. Opinion may shift from favouring homogeneous grouping to heterogeneous grouping and back again to the same original position with no variation and no learning from previous experience. This view of curriculum pattern appears to be near to the truth. The abandoned position in education is reconsidered and later accepted as valid. The new version in a careful observation will reveal that it is different in many ways (Miel, 1971). Thus the pendulum swing is too crude an analogy to describe actual pattern of movement. Further, this view, rests upon either or thinking. Opinion may shift from general science curriculum to specialized subject fields such as chemistry and physics. Thus, the shift is from integration to specialisation. The pattern is repeated though with some modification.

3. The upward and outward spiral

The third way of viewing the curriculum organisation is to think of a spiral which ascends, enlarging as it climbs. The spiral view accounts for the more refined wisdom distilled from the experience over time. The upward and outward curriculum organization acknowledges the gradual nature of development of knowledge and also the development of learner. In the spiral view, the proposals made at a later point in educational history usually are much more refined. At each new point on the upward and outward spiral, the concepts are clearer and the language of education is more precise.

4. Historical Approach

Subjects such as chemistry and physics have a history of development. The current status of knowledge has evolved over time. Both concepts and theories are being subjected to modification in the light of further empirical observation. For example, one of the first attempts to investigate the connection between chemical properties of elements and their atomic masses was made by the German Chemist, Johann Dobereiner (1780 - 1849). He examined groups of three elements such as Chlorine, Bromine and Iodine (known as triads) and noted that Bromine seemed just half-way in its properties between Chlorine and Iodine. Dobereiner's ideas were published in 1829 (see, Nuffield-chelsa Curriculum Trust, 1988). It was in 1864 that the English Chemist, John Newlands (1838 -1898) came up with another classification in which "the eighth element starting from a given one is a kind of repetition of the first like the eighth note in an octave of music." He called his rule the "law of octaves." He arranged all the fifty known elements in the order of atomic mass and demonstrated his law.

It was in 1869 that a Russian Chemist, Dmitri Mendeleev, published the periodic table on which all later versions of periodic table have been based. Mendeleev stated that when the elements are arranged in the order of atomic mass, similar properties recur at intervals. One year later, a German Chemist, Lother Mayer, published a graph (with atomic mass on X-axis and atomic volume in ml per mole on Y-axis) showing wave-like, repeating patterns. He also discovered that the periods differ in length. This sequencing is the historical approach in curriculum organisation.

Apart from the historical approach there are two approaches in 'curriculum organisation that focus on the structure of knowledge. The approaches are - - (1) Type study and (2) Concentric plan. Each of these is described below.

1. Type Study

In type study, the content to be taught is classified into types. A type is a typical representative of a group which exemplifies all the characteristics of that particular group. For example, the halogen group element, chlorine, is a type of the seventh group elements. Most of the characteristics exhibited by chlorine can be expected of other elements too. The type study encourages inductive reasoning and gives training in scientific thinking. However, it should be noted that all content areas cannot be classified into types.

2. Concentric Plan

Concentric plan is comparable to the upward and outward spiral pattern mentioned before. The science course is arranged over a number of years. In the beginning years a general treatment is, attempted (Joseph, 1982). Later, it is developed in successive years according to the mental development of students. For example, consider the topic acids. In the first year, food items having sour taste can be familiarised. In the second year the common properties of acids can be included. In the successive years, strong and weak acids, monobasic and dibasic acids, electronic concept of an acid, etc. can be included. A basic assumption in this organisation is that the learner moves from simple to complex in gradation, with due consideration of the psychological development of the learner.

The concentric plan has two main advantages. One advantage is that there is continuity to what students are learning. The other advantage is that the complexity as well as gradation in the content will challenge the students so to motivate them. However, the criticism that students get disinterested by repeated dealing of the same content every year is meaningless for the depth of the content will draw their attention.

Other than the two patterns based on structure of knowledge, there are approaches in curriculum organization which pay attention to the learner and his/her environment. They are - - (1) Nature study and (2) Nature rambling. These methods lack specificity and are often identified as method of curriculum organi-sation for natural sciences and are not dealt here.

Curriculum innovations in the late 1960s became increasingly involved with chemistry and physics not so much as single subjects but as a part of a larger whole (Waddington, 1984). A number of regroupings were recommended which can be classified into five - - (1) Core Curriculum, (2) Integrated Curriculum, (3) General Science, (4) Physical Science and (5) Integrated Science. Each of these classifications is detailed below.

1. Core Curriculum

Curriculum is defined as "all the learning which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school" (Kerr, 1971, p. 181). The curriculum takes into account the general and special needs of the learner. This is comparable to the 'required' and 'elective' divisions of the traditional subject curriculum. Society needs citizens with both common and differentiated competencies and that the school must provide for these in its educational plan. The terminology *core* has come to be applied to that of the curriculum which is concerned with those types of experiences thought necessary for all learners (Faunce & Bossing, (1967) irrespective of what occupation, they may expect to follow or where they may happen to live.

Core curriculum is designed so as to provide all young people experience, which should help them to live happily and usefully during the years of youth and grow into the full responsibilities of adult life. It is not intended to provide education in vocational skills and knowledge in any discipline. Such intellectual field students may select based on students' personal interest which is not the concern of core curriculum. Core curriculum helps students in the following areas:

1. Proficiency in the use of language
2. Civic understanding and competence
3. Intelligent action as consumers
4. Family relationships
5. Appreciation of beauty
6. Ability to use time efficiently and to budget it wisely, and
7. Respect for other persons and ability to work cooperatively with others.

2. Integrated Curriculum

Integrated curriculum is an approach in curriculum organisation which entails from the view of knowledge as the 'seamless cloak of knowledge,' the 'unity of learning,' or a single view of the world and of life (Pring, 1971). Integration is a pro-word in contrast to fragmentation of the curriculum which typifies the compartmentalisation or pigeon-holing of knowledge, with specialisation.

A subject-based curriculum is said to limit enquiry, set up barriers, and confine study to a limited range of information. It is argued that the division of knowledge into distinct subject divisions is artificial and does not reflect correctly the essential unity of reality and of our ordinary way of understanding and judging. It is foreign to the natural and spontaneous method of enquiry. The disciplines represent the worked out structures of knowledge and the systematic organisation of experience. The disciplines therefore constitute in the most complete and developed form of the logical structure of knowledge. They do not however reflect the pupil's level and mode of understanding, nor do they indicate the process whereby the pupil might attain these structures of knowledge. Thus, the finished product pruned into the logical neatness of distinct disciplines, does not contain within it the way in which it should be presented.

3. General Science

General Science courses emerged at the beginning of the twentieth century as a revolt against the compartmentalisation of different branches of science such as Physics, Chemistry, Botany, Zoology, etc. Some of our important problems require that the teacher and the taught should draw upon many disciplines. For example, our environmental problems require to take an integrated approach not restricted by the artificial boundaries of any one discipline. Disci-plinary boundaries often restrict and tend to limit learners as they investigate problems. Thus, general science stands for an integrated curriculum so as to help learners get an idea that various branches of science are not water tight compartments. Also, general sciencewas based on the idea that it should form an essential part of the general education of all young people, and was seen by its proponents as humanistic as well as scientific in scope, broad rather than deep in content (Waddington, 1984).

Vaidya (1971) lists three aims and objectives of general science courses - - (1) to impart information about the useful products given by science and technology, (2) to provide a comprehensive, consolidated and integrated viewpoint put forward by the various branches of science and (3) to provide training in thinking which is essential to the comprehension of the specialised sciences. However, in view of the outcome of general science curriculum which was in force in the beginning of second half of 20th century it had to be abandoned. The National Education Commission or Kothari Commission Report (1966) made observations against the general science approach which the Secondary Education Commission or Mudaliar Commission (1953) had recommended earlier. As a result of the observations of the Kothari Commission (like a swing of the pendulum) there emerged the disciplinary approach or separate subject curriculum, i.e., Physics and Chemistry.

Physics

The word physics means nature. The word physics is derived from the Latin word *physic* or Greek *Physis*. Physics is the study of nature and the underlying principles that govern the behaviour of the world around us (Wilson, 1981). We are fortunate to have at our disposal the scientific information that has been acquired and applied for the past 7000 years. Even after 7000 years of learning, there is still much we do not know or understand. Physics attempts to describe the process of nature through observation and experimentation, coupled with reflective reasoning, in what we call the scientific method. Theories are tested and natural laws are formulated to describe what appears to be an invariant order in nature.

Physics deals both the macroscopic and the microscopic state of matter (Gupta, 1985). For example, the law of conservation of mass and energy holds good both in the cosmic scale and in the sub-atomic scale. Many laws are generalisations arrived through the method of induction. It is likely that there may be exceptions to the laws which force the scientists to revise the laws. Thus, science (Physics) is not a process by which we go from no knowledge to some knowledge or from some knowledge to total knowledge. Rather, it is a process by which scientists go from some knowledge to more knowledge (Hull, 1988, p. 26).

Chemistry

Chemistry is the science of molecular behaviour. Chemists specialise in interpreting observations on large amounts of material in terms of the properties and interactions of individual molecules and atoms. We trace our origins from the early atomic theories of the Indian Vedas and the Greek philosophers, through the alchemists efforts at transmutations, Lavoisier's discovery of the conservation of matter, Dalton's and Avogadro's brilliant leaps from rather poor data to excellent insights, Maxwell and Boltzmann's Kinetic theory, Mendeleev's and Mayers ordering of the Chemical elements, to the discovery of radioactivity, the atomic nucleus, isotopes, and the still-increasing set of sub-atomic particles (Champbell, 1984, p. 16).

4. Physical Science

Physics and Chemistry have some similarity in the structures of knowledge. Therefore, these two science subjects are combined to form physical science. The description and characteristics of physics and chemistry detailed above have common strands and may be taught using similar methods.

5. Integrated Science

The general science approach described above did not help realise the intended objectives. Separate discipline approach (such as chemistry and physics) also did not provide a coherent view of science. It was, argued that integrated science help make numerous links between its various branches. Integrated approach is associated with the movement to teach science for the majority.

Integration is also a 'pro'-word that is contrasted with the fragmentation of the curriculum which typifies the traditional school with subject barriers, the compartmentalisation of knowledge, with specialisation and little relevance to life as a whole (Pring, 1971).

A subject-based curriculum is said to limit enquiry, set up barriers, and confine study to a limited range of information. Often these barriers are seen to be arbitrary and the integration of subjects is seen as a necessity to have a comprehensive picture of reality.

Chapter IV

STRATEGIES OF TEACHING PHYSICAL SCIENCE

The teaching of physical science employs a number of strategies. Stones and Morris define teaching strategy as "a generalised plan for a lesson which includes structure, desired learning behaviour in terms of the goals of instruction and an outline of planned tactics necessary to implement the strategy" (cited in Sharma, 2003). A physical science teacher can adopt several methods, techniques and models as teaching strategies.

A. Methods of Teaching

The method of teaching refers to regular ways or orderly procedure employed by the teacher in guiding pupils in order to accomplish the objectives of learning situations. In other words, method is a series of related and progressive acts performed by the teacher and pupils to accomplish the general and specific aims of a lesson. In the teaching of science, method refers to the transaction of scientific knowledge and skills by the teacher to students so that they can use them further.

There are several methods for teaching physical science. These methods have been classified into different categories such as oral methods, observation methods and practical methods (Vaidya, 1971). It is possible to classify method by referring to educational philosophies. There are several other classifications such as individualised methods and group methods, child-centred methods and teacher-centred methods. A classification system helps the teacher to be aware of his/her line of action in the teaching learning process.

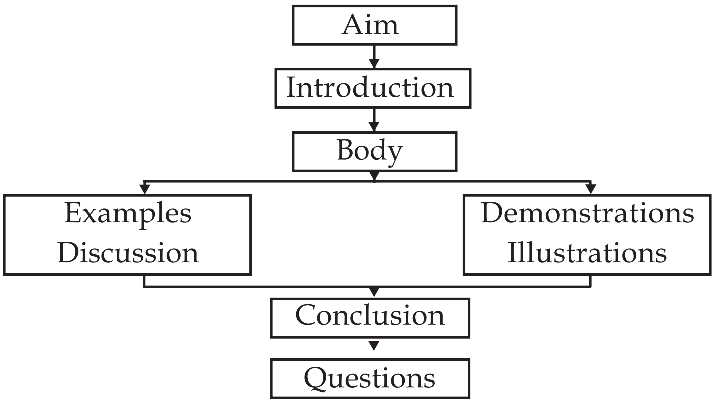
There is a huge body of research literature available on the effectiveness of teaching methods. However, it is very difficult to single out one method as the best that will prove equally successful with every teacher, classroom and content area. The choice of a method is important taking into account the pupil, the content area, the facilities available in the school and more importantly what objectives the teacher is trying to achieve through instruction. A strong knowledge base of the content area is not a guarantee that the teacher will be successful in the process of teaching. Therefore, every science teacher should know the various methodological possibilities and their limitations (Rajan, 1999). A few important methods are detailed below.

I. Lecture method

Lecture method is one of the oldest and most basic pedagogic tool (Mohan, 2002). It is mostly a teacher-centred and expository method involving one-way communication and transmitting a good quantum of knowledge or subject matter to a large number of individuals (Mohanty, 2004).

In this method, the teacher delivers the content to be studied while the pupils listen. In our classroom teaching, the lecture method dominates largely since the teachers have been using this method for years. It is convenient for the teacher, as no practical preparation is needed. According to James Michael Lee, "the lecture is a pedagogical method whereby the teacher formally delivers a carefully planned expository address on some particular topic or problem" (cited in Maitra, 1991).

In lecture method, the teacher is the only active participant and the pupils are passive listeners. They are spoon-fed and their power of observation and reasoning, the exercise of which are so essential in the learning process are not stimulated. However, a teacher can use the lecture very effectively by suitably organising the content to be presented. Mohan (2002) presents a schematic organisation of a good lecture.



Characteristics of a good lecture

Vaidya (1971) lists the following characteristics associated with good lecturing:

1. An enthusiastic presenter who is well organised, challenging and clear in his/her presentation
2. The presentation includes an overview, logical organisation and closure
3. The organisation of the lecture is made explicit to the audience such that they understand the relationship between the various components and parts
4. Verbal and visual clues are provided to emphasise and smooth transitions between elements of the lecture
5. Attention is maintained through appropriate anecdotes, physical activity, humour and especially enthusiasm for the topic
6. The audience is challenged to become intellectually involved with the topic being presented

How to make lecture effective

With a view to make the lecture method more effective, lecturers should consider the following guidelines meant for necessary activities at three distinctive phases. That is (i) preparation (ii) presentation and (iii) evaluation.

1. Preparation

The first step in the process of preparing the lecture is to define the objectives in clear and specific terms. The lecturer should be able to answer the four basic questions - - (1) Who is your audience? (2) What is the purpose of your talk? (3) What is the time available? and (4) What is the subject matter?

The lecturer should be clear about the nature of audience or the students, their background, needs, interests and so on. He should know the duration of the period that his lecture will be delivered. He should also prepare sufficient subject matter or teaching points for dealing with the students. It is advisable to develop a synopsis of the lecture giving the important teaching points at various steps along with a list of reference materials. This can be done by using the following structure - - (a) introduction, (b) body of the talk, and (c) conclusion. Relevant audio visual aids can be thought of while preparing, and adequate preparation for their use in right time and place be made earlier to presentation.

2. Presentation

The written word can only be of limited help when it comes to advise on speaking technique. What is needed is constructive criticism. Some of the essential points to keep in mind are set forth below.

i. setting the scene

ii. covering the material

iii. time for questions at the end

iv. finish on time

v. good posture

vi. proper gestures

vii. fine appearance

viii. suitable manner

ix. courteousness

x. sincerity

xi. voice and tone modulation

xii. vocabulary

3. Evaluation

Evaluation can be done through out the process of lecturing; it will help the lecturer understand whether the ideas being presented are properly conveyed. S/he can get informal feedbacks from the eyes of the audience. Proper questions and feedbacks obtained through evaluation can help the lecturer to be on track and improve upon the methods and techniques followed. S/he can develop a proforma or a small questionnaire for formal evaluation by collecting views of reaction of the students on the lecture. Evaluation can also be done more systematically with the help of a tape recorder or video recorder as in microteaching.

Merits of lecture method

1. The method is economic
2. The method helps the teacher to cover a lengthy syllabus with in a short period of time
3. The method is concise and the teacher always feels secure and satisfied with his/her progress
4. The method is useful in special situations like following (Mangal, 1990):
   a) While introducing a topic
   b) While summarising the subject matter
   c) While giving instruction before performing an experiment in the laboratory
   d) While explaining complicated and difficult experiments
   e) While giving historical accounts of scientific events, scientific discoveries and inventions
   f) While describing the life of great scientists and their achievements

Demerits of lecture method

1. The method is against the principle of learning by doing
2. It does not provide training in scientific method

3. There is no assurance for the teacher whether the students have understood what he/she had taught in the class
4. This method presupposes a class of intelligent pupils who can understand and grasp the lecture with the same speed as they are delivered by the teacher (Sharma & Sharma, 1971). This is practically impossible in our circumstances

II. Demonstration Method

Demonstration is a method, designed to show or illustrate a procedure, process, or phenomenon. In demonstration method, the teacher demonstrates and illustrates certain fundamental phenomena and the application of various principles. A demonstration should not be confused with an experiment because in a demonstration the various variables impinging on the phenomena are not rigidly controlled and varied (Vaidya, 1971).

Demonstration means 'to show'. For example, showing the setting up of an apparatus, the various properties of substances, electrolysis of water, the working of models, etc., can be included in demonstration. This method is in accordance with the maxim of learning - - from concrete to abstract. Successful demonstration in the hands of a teacher provides first hand experience to his/her pupils and through them, s/he can link his/her lessons to major ideas, principles, theories, etc. Demonstration can be best used as a motivating device while introducing a lesson. The demonstration method is usually employed when the apparatus is costly and sensitive and there is chance of damage if allowed to be handled by the pupils (Das, 1985).

Functions of demonstrations

Through careful selection, planning and execution of various types of demonstrations, a teacher can achieve the following purposes in the teaching-learning process (Rajan, 1999):

1. The teacher can introduce experiences unknown to the children, which can become a starting point for their thinking
2. The teacher can provide worthwhile, rich and significant learning

experiences through which the learner can improve the powers of observation and reasoning

3. The teacher can illustrate an abstract idea
4. The teacher can provide concrete experiences for solving a problem

Characteristics of a good demonstration

1. A demonstration should be visible in most of its significant detail to all the members of the class
2. A demonstration should show only one major idea at a time
3. The demonstration should be striking, clear-cut and convincing
4. The aim and purpose of demonstration must be clear to the teacher and the learner
5. The apparatus for demonstration should be arranged in the proper order

Requisites of a good demonstration

1. A good lecture-cum-demonstration room is necessary in which the demonstration table should be visible to all students
2. A good black board for writing important facts and drawing diagrams should be provided
3. Thought-provoking questions should be asked while demon-stration is in progress
4. The teacher should be well-versed in the handling of the apparatus

Guidance for demonstration

Demonstration is a means for the pupil to see how certain things are done. It is important that the teacher should prepare for the demonstration to make it effective. Novice and experi-enced teachers will need to practice the demonstration. The important guidelines for demonstration are listed below:

1. Remember that the teacher is the chief actor in a demonstration
2. Every step should he planned in advance with necessary check-list of items and materials needed
3. Rehearse the demonstration to understand the possible limitations and deviations which are not usually dealt in theory books
4. During demonstrations, it is desirable to outline the steps on the black board
5. The demonstrations should be made simple, assuming the appropriate pre-requisites of the students
6. Do not deviate from the main idea while explanations are given. The explanation in a classroom situation should be addressed to the whole class and not to a single student
7. Make sure that the demonstration is being followed by the students (through questions)
8. Make sure that every member of the class sees the demonstration for which class rearrangement or change in seating arrangement may become necessary
9. Do not hurry through the demonstration. Too much of practice and rehearsal may speed up the demonstration to give the effect of a magic show
10. Do not drag out the demonstration. Unnecessary delay in carrying out the demonstration will adversely affect the demonstration

Merits of demonstration method

1. It is economical in terms of time and expenditure
2. Pupils see actual things and this helps to retain in the memory what they have seen
3. Helps to develop scientific attitude among pupils
4. This method is appropriate for experiments involving hazardous chemicals/costly apparatus

Demerits of demonstration method

1. This method is teacher-centred in which the students are passive listeners
2. There is no scope for developing practical skills as the teacher alone performs the experiment in this method
3. This method does not cater individual differences
4. There is no scope for 'learning by doing' in this method

III. Lecture-demonstration Method

Lecture-demonstration method is a great improvement over lecture method and demonstration method. In this method, in addition to lecturing, the teacher provides some concrete experiences by performing certain experiments or by demonstrating some models.

In the lecture method, the medium of instruction is verbal whereas, in the lecture-demonstration method, there are chances for pupils to observe and draw inferences. The spoken facts and principles are supplemented and reinforced by a series of activities by the teacher and these enable pupils to understand those items more clearly. It is a multi-sensory approach and this method was described as the official method in our schools.

Besides experiments, pictures, diagrams, charts, models, slides, etc., may also be used as illustrative materials, which will help to arouse interest in pupils and make the teaching impres-sive. Teaching by this method has been shown to be as valuable as those of the laboratory method. However, the method demands careful preparation and judicious presentation on the part of the teacher not only in what s/he has to say but also in what s/he has to do.

Merits of lecture-demonstration method

1. Multi-sensory approach is followed in this method
2. The method is often as good as the laboratory method
3. It is economical when compared to individual laboratory work
4. The important maxims of teaching such as proceed from known

to unknown, simple to complex, concrete to abstract and analysis to synthesis are followed in this method

Demerits

1. Pupils do not participate actively
2. No scope for learning by doing
3. The desirable practical skills are not developed
4. It is impossible to demonstrate certain theoretical topics

IV. Historical Method

In this method, the topic is developed from its very beginning and carried through various stages of evolution. Science has its own theory and every invention or discovery has its own historical background. The children feel very much interested and fascinated in listening to the stories and the teacher can introduce his talk with an interesting story. The credit for developing the historical method may be attributed to J. B. Conant of the Harvard Graduate School of Education during 1950s (Vaidya, 1971).

This method is particularly suited to teach scientific theories. Holmyard opined that this method is the only method, which will effectively produce all the desirable results of teaching chemistry (cited in Nair, 1969). It is highly instructive to let the child see how one hypothesis is replaced by another in the light of newly discovered facts. For example, the gradual development of atomic theory can be unfolded in an interesting way if the historical method is followed. Historical approaches in the teaching of science can be classified into two - - (1) biographical or anecdotal and (2) recapitulatory.

In the first type, that is in **biographical** or **anecdotal approach** interesting biographical details and accounts of important incidents relevant to a particular discovery are included in the lesson material at the appropriate place. The emphasis on the events and stories related to the discoveries could be an important corrective to the frequently held erroneous view that science is an impersonal study with no human interest. For example, Archimedes and his bath, Newton and the apple, Kekule and his dream of snake, etc., will always appeal to pupils and may be made the means of arousing interest.

In the second that is in **recapitulatory approach** the order of presentation is retracing of the historical developments. The young pupils resemble the discoverer in being in the beginning of a journey. Therefore, it is more appropriate to conduct him/her along the road followed by the original discoverer. It will emphasise the tentative nature of all scientific theories and the need for constant modification in the face of newly discovered facts. By treating the work historically, whereby encountering changed views (and discarding theories) a beginner is less likely to believe that the latest theory represents absolute truth.

Science in general and chemistry in particular lends itself to the historical method. For example, the gradual development of the atomic theory can be unfolded in a very interesting way. A few important dates and names are included here in this context. The teacher will have to collect, and connect the details to present the example. The dates and name are - - 1800-Volta, 1834-Faraday, 1858-Plucker, 1874-Stoney, 1886-Goldstein, 1897-Thomson, 1911-Rutherford, 1913-Bohr, 1918-Planck, 1926-Sommerfield, and 1932-Chadwick (Rajan, 1999).

Merits of historical method

1. This method is in accordance with child's point of views
2. This method develops in pupils a positive attitude towards science
3. Science has the romance of its own. The striving of the human spirit revealed in the investigation of great scientists has a lasting effect on the learner
4. In many cases, the historical order of events shows how the attempts to meet practical needs have given rise to theoretical considerations. This mode of treatment is particularly beneficial to pupils
5. The historical method helps the students to understand the dynamic nature of science

Demerits of historical Method

1. This method is time consuming
2. The pupils may loose sight of the fundamentals in the huge mass of irrelevant details taught by this method
3. The modern pupil has a large stock of scientific information, which makes it impossible to place him/her at the position of the original investigator. Difficulties encountered by the scientists of early days may not appear as such to the present day school children. Hence, in many cases the historical treatment is not suitable for them.

V. Heuristic Method

The word 'heuristic' is derived from the Greek word '*heurisco*', which means 'serving to discover' (I found out). Henry Edward Armstrong of the Imperial College, London, developed this method. According to Armstrong, the real purpose of science is original investigation and discovery. Therefore, the pupil must be put in the position of an investigator to discover the principles of science for himself/herself. Armstrong defined the heuristic method of science as "those method which involve our placing of students as far as possible in the attitude of the discoverer, methods which involve their finding out instead of being merely told about things" (cited in Nair, 1969). Science is a practical subject and this method advocates the correct way of learning as 'by doing.'

Principles of heuristic method

Joseph (1982) listed the following principles underlying heuristic method:

1. Principle of activity
2. Principle of logical thinking
3. Principle of proceeding from the known to the unknown
4. Principle of purposeful experience
5. Principle of self-thinking and self-study

Procedure

The student is required to solve a number of problems experimentally. Each student is given an instruction sheet and is required to perform a number of experiments pertaining to the problem. The instruction is made as simple as possible. The pupil performs the experiments with a bit of guidance from the teacher and keeps a record of the observations. S/he has to draw conclusions himself/herself and work out their bearings on the problem at hand. Thus, s/he is led to reason from observation.

The heuristic method demands discovery rather than dogma; mental and physical activity on the part of the student in place of passive receptivity. Westaway commented about the heuristic method - - "Essentially, therefore, the heuristic method is intended to provide a training in method; knowledge is a secondary consideration altogether" (cited in Rajan, 1999). The method emphasises the learning process and discourages the stuffing of pupils' minds with facts and principles. All the steps in problem solving, viz., identifying the problem, formulating a hypothesis, collecting data, testing the hypothesis and verification have received adequate weightage in heuristic method.

Merits of heuristic method

1. This method is based on the principle of learning by doing
2. This method provides for proper training in the method of investigation
3. Learning becomes free and spontaneous since students attack problem, without any external restraints
4. This method develops scientific interest and attitude in pupils
5. This method helps to develop self-confidence, self-reliance and perseverance

Demerits of heuristic method

1. This method demands an exceptionally brilliant teacher, a very small class size and a well-equipped laboratory and library which are not usually realised in practice

2. It is too expensive to be adopted in schools
3. Pupils do not get the benefit of others' experience as Issac Newton once observed - - "If I have seen farther than Descartes, it is by standing on the shoulders of giants"(Wilson, 1937)
4. Most students are neither capable of any original investigation nor they have the necessary ability and required knowledge to design and perform original experiments

VI. Problem Method

The adoption of some of the desirable elements of heuristic method has led to the development of problem method. It differs from the heuristic method in that the problem is found and solved by the class as a group under the leadership of the teacher. The method is designed to give each pupil a thorough training in scientific method of solving problem. "Problem method enjoys the highest prestige as compared with other methods of science leaching amongst science teachers all over the world" (Vaidya, 1971).

Vaidya (1971) has defined problem solving in different ways. Problem solving can be defined as "the process of raising a problem in the minds of students in such a way as to stimulate purposeful reflective thinking leading to a rational solution." "It is a planned attack upon a difficulty or perplexity for the purpose of finding a solution." Students should be frequently confronted with scientific problems, for they provoke thinking and test the quality of the concepts formed during teaching.

Problem method involves the following stages - - (1) identifying the problem (2) collecting data (3) formulating a hypothesis (4) testing the hypothesis (5) verification (Siddiqi & Siddiqi, 1983; Gupta. 1985).

Procedure

As thinking originates in a recognised perplexity, so to teach each unit we must start with a problematic situation. The ideal is to have the problem raised spontaneously in the minds of pupils as a logical need brought about by a discussion. The teacher should select situations containing such problems and initiate discussion in order to stimulate curiosity. Subsequently this must challenge the intellect of the students to attempt a solution. The problematic situation should be clearly understood by the pupils and the solution must appear worthwhile and desirable. Generally, pupils' interests or experiences should be mobilised to provide suitable problematic situations (Nair, 1969).

Teacher's role in the problem solving method is very important, s/he has to set up an atmosphere of freedom and help so as to develop in the student an attitude of open mindedness, critical inquiry and attitude of respect for others point of view. S/he has to eliminate bias and encourage wide reading.

Merits of problem method

1. This method develops the capacities of planning, thinking, reasoning, critical enquiry and initiative
2. This method arouses a natural interest in solving problems
3. This method helps in organising and integrating knowledge and experience
4. This method instils in the learner the social values such as co-operation

Demerits of problem method

1. This method is not suitable for topics that are descriptive in nature
2. In this method, the individual differences do not receive adequate attention

VII. Project Method

Project method originated as a revolt against the old system of education, which imposed the needs and interests of the adults on the child and considered the child a passive entity. Kilpatrick and Stevenson are the proponents of this method. According to W. H. Kilpatrick, "a project is a whole-hearted purposeful activity proceeding in a social environment." J. A. Stevenson defines it as "a problematic act carried to completion in its natural setting." Ballard defines project method as "a bit of real life that has been imported into the school" (cited in Vaidya, I971; Sharma & Sharma, 1971).

As education is closely related to life, this method prepares students for real life through "learning by doing". Such learning is real, meaningful, permanent and applicable. As students take interest and initiative in projects their whole-hearted co-operation and effort can easily be ensured. Joseph (1982) listed the following basic principles of the project method:

1. The principle of purpose
2. The principle of activity
3. The principle of reality
4. The principle of freedom
5. The principle of utility

The following are the major steps of the project method (Sharma & Sharma, 1971; Joseph, 1982; Kohli, 1986) - - (1) Providing a situation (2) Proposing the project (3) Planning (4) Execution (5) Evaluation (6) Recording. Each step is detailed below.

1. Providing a situation

The teacher should provide situations wherein the pupils feel a spontaneous urge to carry out a particular project. A field trip, news, an article, a video-clipping or any such exposure can help in providing a situation.

2. Proposing the project

In proposing a project, interests, attitudes and abilities of the students should be taken into account. To facilitate the process of proposing a project, formal and informal discussions with students based on a topic will be necessary. The project should be acceptable to all students. The resources in the locality are of prime importance in the selection of a project.

3. Planning

The students have to plan out the details of the project regarding different materials needed, number of groups to be formed, availability of books, resource persons to be contacted, time allotment to each group, nature of the final product, total time needed, equipments available and such details necessary in each project.

4. Execution

This is the most important and long step in the project method. At this stage, the teacher as well as pupils should be careful, since there may be several problems that they may have to face, which were not anticipated at the planning stage. The teacher should guide, encourage and monitor the progress of the project and should give instructions if necessary.

5. Evaluation

After the project has been completed, it is essential to review the whole work, find out the mistakes if any, and suggest improvements. The students must get opportunity to report their own failures and findings.

6. Recording

The students should keep a complete record of the different steps of the whole project.

There can be different kinds of projects. The following type of projects has been suggested by Kilpatrick. They are (cited in Joseph, 1982) - - (1) producer type (2) consumer type (3) problem type (4) drill type. According to Prasad (2004), following types of projects can be done by secondary school students - - (1) observation project (2) constructive project (3) experimental project (4) survey project (5) research project (6) scientific investigation project. A science project can be any enriching science experience. Science projects develop research attitudes, which many result in discoveries. Some students are not good in remembering facts and figures. They get a chance to demonstrate their skills by carrying out projects (Beller, 1982).

Merits of project method

1. The method satisfies the specific needs and interest of the participants

2. The learners are purposefully and profitably occupied
3. The method provides educationally rich and stimulating experience
4. The method helps to correlate different subjects
5. The method helps to develop democratic way of living and learning

Demerits of project method

1. The method disorganises the work of the school
2. Teachers hardly get time to provide the suitable situations and to organise the work
3. A project may have relevant materials in different subject areas and the teacher will find it difficult to support students in their efforts

VIII. Developmental Method

Most of the books available on science teaching do not detail the developmental method. A few books dealing with develop-mental method details it differently. Washton (1961) describes developmental method as a combination of inductive and deduc-tive reasoning (p. 197). The method takes on a new aspect of an experiment or a problem. The teacher and pupils interact constantly which leads to the specific experimental details or to the specific aspects of the problem. Based on the question-answer session and discussion the pupils will be given time for writing up their observations along with the results of their discussion. The method can be used in the laboratory as well as in the classroom. The essential nature of the method is that of a problem solving experience. Careful questioning and interaction on the part of the teacher is very important. The challenge presented in the experiment or problem helps to maintain a high degree of interest.

However, Joseph (1982) has described the method with the Herbartian steps - - preparation, presentation, comparison or association, generalisation or definition and application (p. 202). The merits and demerits are identical to the problem method.

Merits of developmental method

1. It gives training in problem solving method
2. There is constant interaction between the pupil and teacher
3. The method is in accordance with the psychological principles of learning
4. The method arouses interest, stimulates thinking and cultivates scientific attitude in pupils

Demerits of developmental method

1. Pupils are not given opportunities for developing laboratory skills
2. It demands a lot of work from the teacher
3. The method is not child centred (Joseph, 1982)

IX. Individualised Laboratory Method

Teaching of science without a laboratory is a futile attempt. Laboratory is an integral part of teaching science. Experimentation not only verifies the theories but also help in clarifying many misunderstandings and misconceptions. The concept of cause and effect is strengthened in a laboratory. Through individualised laboratory method, the students are able to,

(1) Retain facts learnt in theory classes

(2) Satisfy their interest and curiosity, and feel emotionally satisfied when they see that they are able to do something on their own

(3) Acquire training is scientific method

(4) Acquire scientific attitude

(5) Acquire skills of handling various apparatus

Individualised laboratory method provides opportunities for each student to conduct experiment at his own desk in the science laboratory; the responsibility for performing experiments is shifted from the teacher to the pupils. Every pupil is provided with the laboratory manual containing instructions and the teacher guides and supervises pupils' work. The laboratory thus becomes a place where the teacher and the taught solve their problems together.

The teacher divides the apparatus required for experiments into two groups, reserves one group to be performed by him at the demonstration table and the other to be conducted by the pupils in the laboratory. In the case of delicate and costly apparatus, the teacher himself can perform the experiment, which the pupils observe and make their conclusions (Joseph, 1982).

Preparation for laboratory work

For the laboratory work to be effective, the following points should be taken into account:

1. The laboratory should be systematically and skilfully organised
2. The laboratory periods should be perfectly correlated with the class work
3. The pupils should be told before hand about the setting-up of apparatus, recording of the result and particulars to be taken care of. They must also be asked to collect all necessary directions for the proper conduct of the experiment from textbooks
4. Students should be asked to bring a laboratory workbook wherein they must have entered all the necessary equipments and draw neat diagrams and tables for the entry of the results
5. Pupils whose preparation of work is found unsatisfactory should not be allowed to do the practical work
6. Apparatus should be available in good condition and should be arranged before the commencement of practical classes

Role of the teacher

The teacher must constantly note the progress of every student and should be the leader, inspirer and guide. S/he should give adequate instruction wherever necessary, check the results, and correct them if necessary.

Record of experiments

Every student should have a record book to record the results of the experiments. The format includes - - (1) purpose of the experiment (2) apparatus used for the experiments (3) procedure (4) result (5) conclusion (Joseph, 1982).

Merits of individualised laboratory method

1. It is a child assertive method
2. It ensures active involvement of students
3. It inculcates manipulating skills and laboratory techniques

Demerits of individualised laboratory method

1. It is highly expensive
2. It is time consuming
3. The dull students are often tempted to copy down the result of brilliant ones
4. It is a tedious process for the teacher to perform his/her role in this method

X. Supervised Study

Supervised study provides a practical method of teaching pupils how to study and as such, it has important place in any scheme of modern education. It gives the teacher a chance to render individual help, remedial teaching and guidance to the learners whose learning strategies are essentially varied (Rajan, 1999). Supervised study is a method of teaching intended to promote optimum learning. It gives effective direction and oversight of silent study and laboratory activities of pupils. The chief aim of supervised study is to help the pupils acquire good study technique and become efficient learners. The teacher acts as the director of the learning process.

Activities during supervised study

The teacher can make use of some of the following tasks:

1. Teaching pupils memorise effectively
2. Teaching pupils read rapidly with understanding

3. Guiding pupils in using reference books, maps, charts, diagrams, etc.
4. Guiding pupils in the preparation of notes and reports
5. Assisting pupils in the formulation of hypotheses
6. Guiding pupils in direct observation of apparatus and specimen
7. Guiding pupils in interpretation of data, graphs, formulae, etc.
8. Supervising in collecting and organising data
9. Teaching pupils how to gather immediate feedback, verify results and progress systematically

Planning for supervised study

Supervised study can be organised in different modes, some of them are listed below (Joseph, 1982).

1. **The double period plan -** in this mode, one period is allotted for class activity and the other for supervised study under the guidance of the teacher.
2. **The daily extra period plan -** here, an extra period is allotted for supervised study. The teacher will be available after the class.
3. **The library study plan -** in this type, pupils may go to the library and work on assignments under the supervision of the teacher.
4. **Divided period plan -** here, one period is divided into two parts - first part for class activity and the other for supervised study.

Advantages of supervised study

1. It enables the teacher to give individual attention to pupils
2. The pupils get thorough training in study habits
3. It makes the child responsible and self-reliant
4. It creates better teacher people relation

Disadvantages of supervised study

1. It requires good library, laboratory and reading rooms
2. This method requires additional teachers

XI. Dalton Plan

Dalton plan is a scheme of educational reorganisation rather than a specific method to teach one or more subjects. Dalton plan was developed by Miss Helen Parkhurst in 1920 and was tried at Dalton High School, Massachusetts, USA. It recognises the individuality of the child and aims at giving him or her freedom and making the school a community, where mutual interaction of individual and group is possible. It approaches the whole problem of work from the pupil's point of view, giving him/her more responsibility and interest in his/her education. It is intended to be a method of study that calls for the kind of intellectual and moral habits that are so essential for the development of a responsible and successful citizen. The school is conceived to be a sociological laboratory where the children are the experimenters and the teachers are observers ready to give expert advice where so required (Nair, 1969).

The Dalton plan replaces classrooms by subject laboratories. The class exists only as a unit of organisation and not as a unit of instruction. Curriculum consists of two parts - major subjects and minor subjects. The major subjects include science, history, geography and language and the minor subjects include music, arts, and domestic science. The classes are held in two sessions. The classes for the major subjects are arranged in the forenoon and the classes for minor subjects are in the after noon. The work in the different subjects for the whole year would be divided into smaller units or assignments known as contracts; monthly, weekly or daily. The assignment contains elaborate instructions about the things to be done by the pupils, precautions, reference materials, appliance to be used, self-testing devices and so on. There is no fixed time-table but the only condition is that the student should finish the assignments. Superior or brighter students might receive additional assignments for enrichment. At the end of each month or contract period, the student is given a test at his/her request.

Principles of the method

The major principles underlying Dalton plan are:

1. The principle of individual work
2. The principle of freedom
3. The principle of self-effort
4. Principle of Gestalt view of work

Procedure of Dalton plan

Students go to the subject laboratories and work at their own convenience and pace. They are free to discuss their work with others and with the teacher. There is no fixed timetable for the work. The teacher goes about helping and guiding them in referring books, conducting practical works and taking notes. Every student signs a contract for the works to be done during each month. A detailed assignment is given to the students, which forms the basis of his/her work.

The success of the plan depends on the careful preparation of the assignment. The subject matter included in the assignment should be adequate to do the job. It includes books to be referred, observations to be made and experiments to be performed. It should also contain brief explanations of points requiring clarifications, helpful suggestions and precautions to be observed while performing experiments. In Dalton plan, each pupil's progress is recorded separately in a card called job card.

The teacher's role in Dalton plan is to provide an atmosphere of study. S/he should clarify their doubts regarding assignments. The teacher assumes the role of advisor and does not interfere with the pupils' work as long as their progress is satisfactory.

Advantages of Dalton plan

1. Teaching is individualised
2. Continuity of work is ensured
3. Self-effort brings confidence in pupils

4. Develops initiative and resourcefulness
5. Problem of discipline is solved

Disadvantages of Dalton plan

1. It is impractical in ordinary schools
2. Preparation of assignments needs much expertise
3. It denies group activity
4. Pupils left alone in laboratory are likely to attempt indiscriminate experimentation, which may result in damage of the apparatus and materials (Joseph, 1982).

XII. Differential teaching

Differential teaching is adjusting the teaching according to individual differences. In a class, there will be gifted, average and slow learners. In this method different programmes will be given to these groups. Among the slow learners, there may be physically and mentally challenged children. Special training should be given to mentally and physically challenged children. This kind of teaching is called differential teaching.

The classroom teaching involves tasks with varying degrees of complexity and difficulty or with difference in subject matter in tune with the individual abilities, needs and interests. There are three basic procedures in differential teaching.

1. Assigning individual projects accounting for individual differences
2. Dividing the class into several heterogeneous groups so that a variety of talents may be shared or using more homogeneous groups each assigned with different activities
3. Designing home-work assignments with built-in choices

XIII. Cooperative Learning

Cooperative learning, although developed in the 1950s by Thelen (1954) has been widely implemented and researched since 1970s. Today there are many methods of cooperative learning developed by different researchers. Well-known scholars like Slavin (1978), Johnson and Johnson (1986), Sharan and Shashar (1988), and Kagan (1992) spearheaded the development of cooperative learning.

Cooperative learning is defined as "students working together to attain group goals that cannot be obtained by working alone or competitively" (Johnson & Johnson, 1986). It is an act of learning together. It promotes creative thinking by increasing the number of ideas, quality of ideas, feelings of stimulation and enjoyment and originality of expression in creative problem solving. Here the students are triggered by the ideas of others and different perspectives cause group members to consider a large number of alternatives.

Theoretical framework for cooperative learning

In cooperative learning, Slavin (2000), values two major theoretical bases for learning - - 'motivational' and 'cognitive.' With respect to the motivational aspect, cooperative learning persists in the significance of incentives as motivators for further cooperation to facilitate and deepen learning. Therefore, it appreciates the creation of a context in which group members can attain their personal goals only through group attainment. As far as the cognitive aspect is concerned, cooperative learning helps students to acquire critical thinking skills.

Richards and Rodgers (2001) argues that cooperative learning possesses its own theory of language and theory of learning. In its theory of language, cooperative learning sees language as a tool for social relations. Students are provided with authentic contexts for negotiation of meaning through use of the language. In its theory, cooperative learning is based on the works of developmental psychologists like John Dewey, Jean Piaget, Kohlberg and especially Lev Semenovich Vygotsky; all these works accentuate the central role of social interaction in learning, which promotes collaboration and eventually independent problem solving.

Elements of cooperative learning

Stahl (1996) enumerates the following elements of cooperative learning that are essential for successful implementation of cooperative teaching-learning situations.

1. A clear set of specific learning outcomes: Teachers should describe in very unambiguous language the specific knowledge and abilities students are to acquire and then demonstrate on their own
2. Collective "buy in" to outcome objectives by all students in the group: Students must collectively accept the expected results as their own and as something, they want to achieve individually and as a team
3. A clear and complete set of task-completion instructions: Teacher must provide directions that describe in clear, precise terms what students in their respective groups are to do, in what order, with what materials
4. Heterogeneous groups: Teacher should organise the three, four or five member small groups. So students are mixed as heterogeneously as possible, first according to academic abilities and then based on ethnic background, race and gender
5. Equal opportunity for success: Each student must perceive that s/he has just as much chance to learn the content and abilities and to learn the group rewards for academic success by being in the group
6. Positive interdependence: Within co-operative learning situations, students have two responsibilities - - a) learns the assigned materials and b) ensure that all members of the group learn the assigned material. The technical term for this dual responsibility is positive Interdependence
7. Face to face promotive interaction: For all the group works, students should arrange themselves so that they are positioned and postured facing one another to enable direct eye contact and face-to-face academic conversations. Promotive interaction is defined as individuals encouraging and facilitating each other's efforts to achieve and complete tasks to reach the group's goals
8. Positive social interaction behaviours and attitudes: To work together in a group as an effective academic team, students must

engage in such interaction abilities as leadership, trust building, conflict management, constructive criticism, encouragement, compromise, negotiation and clarification

9. Access to must-learn information: Students must have access to and comprehend the specific information that they must learn and that is aligned directly with the outcome objectives and the test items that will be used to measure their academic achievement
10. Opportunities to finish must-complete information processing tasks: For students to be successful, each must complete a number of internal information processing tasks aligned with targeted objectives
11. Sufficient time-spent learning: Each student and each group must be given the time to learn the targeted information and abilities to the expected extent
12. Individual accountability (personal responsibility for learning the targeted content and abilities): Individual accountability exists when the performance of each individual member is assessed, the feedback to the individual and the group to compare against a standard of performance, and the member is held responsible by group mates for contributing his or her share to the group's success
13. Public recognition and rewards for group academic success: The teacher grades the individual tests, computes the average scores per team, and determines the appropriate team prizes. The students receive awards on the day following the test
14. Post-group reflection (debriefing) within group behaviours: Students must spend time after group tasks to systematically reflect upon how they worked together as a team. They should discuss group maintenance; social and group processing behaviours, roles, and attitudes; and particular behaviours and attitudes; that promote or prevent the group's and individual member's success

Thus, cooperative learning involves the working together of students to achieve the shared learning goals by ensuring that, they and their group mates have successfully completed the learning task assigned to them.

Types of cooperative learning

The types of cooperative learning adopted in our classroom include following:

1. Formal cooperative learning

This is the most widely used method. Formal learning groups involve students working together, for one or several class sessions, to achieve shared learning goals and complete jointly specific tasks and assignments. These groups provide the foundation for all other cooperative learning procedures. They are structured through the following sequence.

(i) Specify the student outcome objectives for the lesson

(ii) Make a number of instructional decisions

(iii) Explain the task and the position interdependence within the groups to provide task assistance or increase students' interpersonal and groups skills

(iv) Evaluate students' learning

(v) Help students' assess how well their groups functioned

While forming small formal cooperative learning groups for students conducting experimental activity, the roles may include organiser, record writer, assistant, and observer. The goal of the teacher is to maximise interdependence and active learning among students. Students become capable of organising themselves as they gain experience.

2. Informal cooperative learning

An informal cooperative learning group is one in which students work together in temporary, ad-hoc groups that last for only one discussion or class period to achieve joint learning goals. Informal cooperative learning groups are used to focus sufficient attention on the material to be learned, create an expectation set and mood conducive to learning, ensure and provide closure to an instructional session. The one-period long group work activity designed for conducting any laboratory work in small groups (usually three to four students) is an example of an informal cooperative learning group.

3. Cooperative base/home groups

These are long-term heterogeneous cooperative learning groups with a stable membership, whose primary responsibility is to give each member support, encouragement, and assistance needed for each one to progress academically, develop cognitively and socially in a healthy way.

Base groups may also be responsible for letting group members who were absent know what went on in the class when they miss a session. Informally everyday, members interact within and between classes, discussing assignments and helping one another with homework. The use of base groups tends to improve attendance personating the work required and the school experience, and improve the quality and quantity of academic achievement. The larger the class or school, the more complex and difficult the subject matter, the more important it is to have base groups.

4. Cooperative learning scripts

Cooperative learning scripts are standard procedures for conducting repetitive lessons and managing classroom routines. These repetitive lessons provide a base on which the cooperative classrooms may be built.

Steps involved in cooperative learning.

Kagan (1992) lists the following steps in the cooperative learning:

1. Student centred class discussion

In this, the students are motivated to invent and express their own interest in the subject covered. The aim of the discussion is to increase their involvement in the topic by stimulating their curiosity. The discussion should lead to an understanding among all students and the teacher, about what the students want to learn and experience in relation to the topic. Thus cooperative learning is a process that flows out of the interests of the students.

2. Selection of student learning teams

The students may be assigned to teams or may be allowed to select their teams, depending on the goals of the class. By maximising the heterogeneity among the students' teams, the teacher increases the probability of establishing positive peer tutoring, improving ethnic and social relations, increasing role-taking abilities, and improving self-esteem among the students. Thus teams assigned by the teacher on the basis of heterogeneity increase the need for team-building experiences.

3. Team-building

Several team-building techniques have been designed. They are designed to introduce students to each other and for overcoming resistance among students. Two of these techniques are interview and round table brain-storming. Interview helps students to introduce each other. Round table brain-storming produces a strong team identity, a willingness to work in teams and a sense of the mutual interdependence of the team-mates and the need for cooperative interaction.

4. Team topic selection

The teams are allowed to select the topics for their team. Before doing this, the teams are reminded which topics the class as a whole has indicated are of greater interest. The team-mates are encouraged to discuss among themselves the various topics so that they can settle on the topic of most interest to themselves as a group. As the teams discuss their interests and begin to settle on a topic, the teacher circulates among the teams and acts as a facilitator. Thus each of the teams will settle on a topic and will feel identified with its topic.

5. Minitopic selection

Individual students are encouraged to select minitopics, each of which covers one aspect of the team topic. Minitopics may have some overlap, and the students within teams are encouraged to share references and resources, but each minitopic must provide a unique contribution to the team effort. The teachers may require that minitopics meet the approval of the teacher because some topics may be appropriate to the level of a given student, or because sufficient resources may not be available on a given topic.

6. Minitopic preparation

The preparation of minitopics takes different forms, depending on the nature of the topic. The preparation may involve library research, some form of data gathering, the creation of an individual project, interviews of experts, the planning of an individual contribution to a group project, or introspection. All of these activities take on a heightened interest when the students know that they will be sharing the fruits of their labour with their team-mates.

7. Minitopic presentations

The minitopic presentations and their discussion within teams is an extremely important step in cooperative learning. Minitopic presentations and discussion within teams are done so that all of the team-mates are exposed to the knowledge or experience acquired by each, and so that they can actively discuss the topic as a panel of experts. In the preparation of the minitopic presentations, the teacher may review the principles of active listening, interviewing and supportive questioning. Thus the team presentation becomes far more than, the sum of the mini-presentations.

8. Preparation of team presentations

The teams are informed of how long their presentations will be, and they are encouraged to plan a presentation that will be interesting and informative. Non-lecture formats such as debates, displays, demonstrations, skits, etc., are encouraged. The use of blackboards is also encouraged. Some teams find it useful to make a media presentation such as slide show, OHP, etc.

9. Team presentations

The team members become responsible for how the time, the space and the equipment of the classroom are to be used during their presentations. One of the greatest difficulties that students have with their first team presentation is managing time. So there is a need to appoint a class timekeeper who is not a member of the presenting team. The teacher may find it useful, following the presentation, to lead a feedback session and/or to interview the team so that other teams can learn something about what was involved in the process of developing the presentation.

10. Evaluation

In this the teachers may wish to elicit comments from the class in order to evaluate each cooperative learning unit after all teams have made their presentation on that unit. Following each team presentation, the teacher may guide a class discussion of the strongest and weakest elements in the content and the format of the presentation. Some teachers and students find it comfortable to derive individual grades from the minitopic papers, the minitopic presentations, and the team presentations. Others prefer to make learning and sharing their own reward.

Requisites of an effective cooperative learning situation

There are certain factors needed for cooperative learning for its smooth functioning. They are:

1. **Group formation:** This is the planning process in which, the teacher engages to compose the most efficient grouping based on the goals of the experience. It involves the aspects such as assigning students to groups, size of the group, composition of the group, and classroom arrangement.
2. **The role of teacher:** The role of the teacher in cooperative learning is summarised as follows:
   - (i) Specifying the objective for the lesson
   - (ii) Making decisions about placing the learning groups before the lesson is taught
   - (iii) Explaining the task and goal structure to students
   - (iv) Careful observation and supportive intervention-monitoring the effectiveness of the cooperative learning groups and intervening to provide task assistance or to

increase students interpersonal and group skills

(v) Evaluating the student's achievement and helping students discuss how well they collaborated with each other

3. **Assessment:** The assessment of cooperative learning situation can be done at two levels - (i) assessment of individual performance and (ii) assessment of group performance.

Cooperative learning must be used predominantly to prepare students to live in interdependent, diverse and rapidly developing world. Therefore, cooperative learning is uniquely suited for science teaching.

B. Techniques of Teaching

Teaching methods can be implemented through different techniques of teaching. Methods of teaching determine the way or style in which content is to be presented whereas, a technique of teaching assists or helps in the presentation of content in teaching-learning process. Teaching methods reveal how content is presented in classrooms, while techniques indicate the activities to be followed in teaching. Techniques are logical as well as psychological in nature. Sometimes the nature of the content is most important in employing a particular technique of teaching. A method includes several techniques of teaching and one technique employs several maxims of teaching. There are different teaching techniques such as questioning, narration, description, explanation, exposition, illustration, storytelling, etc. (Sharma, 2003). Two important small group-teaching techniques suitable for classroom practice - buzz session and brainstorming - are discussed below.

I. Buzz Session

Buzz session is a small group technique with a high degree of student involvement. This technique is employed during the course of a lecture or some other similar programme where the students become motivated and seized with the issues involved (Vedanayagam, 1988). The success of buzz group techniques depends on the awareness and compliance of the rules and procedure of the technique on the part of students.

Organisation of buzz session

A typical way of organising a buzz group technique initially consists of dividing the class into different sub-groups of six to seven members. The subgroups are then given a minute to select a discussion leader and a rapporteur. It is the responsibility of the leader of the sub-group to see that each member of the group expresses himself/herself freely. After the discussions, the groups reassemble to reconstitute the original large group. The rapporteur of each sub-group then presents the summary of the reactions of the group members to the original presentation. If the members raise any question, the rapporteur should answer it during the course of discussion. The unresolved points (if any) are referred back to the concerned groups for the subsequent discussions and reporting to the plenary session once again. Finally, the general group reaches a consensus regarding the solution of the concerned problem.

A teacher can use the buzz session at the beginning of the school year to help students get to know each other. In such a situation, students can talk about themselves, their interest, hobbies and other matters of concern.

Advantages of buzz session

1. It promotes critical thinking among pupils
2. All aspects of a particular problem can be discussed
3. It ensures the involvement of all its participants
4. Helps to develop social skills

Disadvantages of buzz session

1. It needs expertise from the part of teacher
2. It cannot work fruitfully in lower classes

II. Brainstorming

Brainstorming is an activity designed to promote creativity. This technique was developed by Osborn. It is a problem-oriented strategy of teaching. This is a form of discussion which enables the group to do collective and creative thinking. The emphasis is on eliciting of as many different ideas as possible for more careful considerations later. This strategy is based on the assumption that a student can learn better in a group rather than in individual study. This is completely a permissive style of teaching strategy.

In brainstorming technique, the higher order objectives in cognitive and affective domains can be achieved. This strategy consists of a problem-solving situation in which the learners are assigned a problem and they are asked to discuss any idea which come to their mind. The group is encouraged to provide even unusual suggestions. They have to analyse and evaluate the workability of their own suggestions of the problem. There should be a person to lead or guide the different groups of the programme and is called anchor. Anchor has to record all the ideas generated during the discussion.

Stages in brainstorming

(1) **Warm up -** in this stage, anchor presents the problem formally and asks different groups to express their ideas freely. The anchor should make the situation more interesting for the groups so that they can express freely. In the classroom situations, normally the teacher takes the role of anchor. After three or four sessions, his/her role can be given to students. Warming up can be done by citing an event, through a small story or through an interesting description.

(2) **Ideation -** this is the stage where the groups express their ideas freely. The anchor should make sure that all the ideas are recorded.

(3) **Evaluation -** this is the last stage and in this stage, the evaluation of different ideas is done. The criteria, which are formulated through discussion, are used as references to evaluate the ideas. From these, the most suitable idea is selected as the solution of the problem under consideration.

Principles of Brainstorming

For brainstorming to be effective, it should be based on the following principles:

(1) Freewheeling: Once the brain storming session is started, it should work as a free wheel. It means that there should be no obstructions to express the ideas. The ideas may be irrelevant or foolish. Whatever it may be, the group can express it.

(2) No criticism: There should be no such act which hinders the ideas of groups; even gestures should be avoided.

(3) Quantity breeds quality: As the number of ideas (quantity) increases, there will be more ideas, which are relevant to the purpose. The anchor should encourage the group to give more ideas.

(4) Hitch-hiking: For the formulation of a suitable solution to the problem, the different ideas can be adopted or accepted. Based on these ideas, we can create and modify new ideas. Hitch-hiking is a popular usage; a person reaches his destination with the help of others.

Steps in brain storming

1. Plan all phases of the problem and think about the sub-problems which may emerge
2. Select sub-problems to be attacked
3. Think about the differences which may help involving them
4. Select the probable sources of data and collect the most relevant data
5. Decide the possible ideas through free-wheeling with suspended judgements, which hints to the solution
6. Select ideas that are most likely to lead to the solution
7. Consider possible ways to test these ideas
8. Test the ideas in terms of relevance, adequacy and sufficiency
9. Imagine all possible contingencies and ways of meeting them

10. Take decisions about the final solution of the problem

Advantages of brainstorming

1. It has both psychological and educational basis of teaching
2. It is a creative strategy of teaching and encourages for eliciting original ideas
3. It provides a number of ideas of good quality
4. It creates the situations for independent thinking among learners

C. Models of Teaching

Models of teaching deal with a rich variety of approaches to the problem of teaching. They are intended to help teachers to provide meaningful effective learning situations. It provides guidelines what to teach, how to teach and what actions to take while teaching. A model of teaching contains steps and procedures to generate desired outcome in learning.

Model of teaching is defined by Joyce and Weil as a plan or pattern which can be used to design classroom instruction and shape instructional materials including books and curricula (cited in Aggarwal, 1995). There are a large number of learning models that students can easily respond, and complex ones, which the students gradually acquire through skilful instruction. Some models aim at specific objectives; others have a broader usefulness.

Models of teaching are really models of learning. The ultimate outcome of good teaching is good learning. "As we help students acquire information, ideas, skills, values, ways of thinking, and means of expressing themselves we are also teaching them how to learn" (Joyce & Weil, 2003). A model of teaching must enable the students to learn more easily and effectively and to develop the knowledge and skills required to master the learning process systematically. Effective learning must create powerful learners.

Characteristics of a teaching model

Aggarwal (1995) lists the following characteristics for a good model:

(1) **Specification of learning outcome -** a model of teaching specifies what the students should perform after completing an instructional sequence. It specifies the exact learning outcomes.

(2) **Specification of learning environment -** a good teaching model specifies in definite terms the environmental conditions under which a student's response will be observed.

(3) **Specification of criterion of performance -** a model of teaching specifies the criterion of performance, which is expected from the students.

(4) **Specification of operations -** a model of teaching specifies the mechanism that provides for the reaction of students and interaction with the environment.

(5) **Scientific procedure -** a model of teaching is based on a systematic procedure to modify the behaviour of the learner.

Methods of teaching and models of teaching

Models of teaching differ from methods of teaching in many aspects. A method stands for the dissemination of content. However, models of teaching aim at the realisation of pre-determined objectives besides content transaction. Presentation of the content is the core process of any teaching method, whereas models of teaching emphasise on definite stages known as phases for its presentation. The content to be presented determines the method adopted, while the objectives to be achieved determine the teaching model. Method is generally a mode or way of presentation; different methods can be used for presenting one subject matter. Models are instructional designs; it refers to formal structure of the sequence of acts to be carried out in classroom and other settings. Generally, models of teaching are supported by sound theories of teaching and learning. Moreover they give emphasis to metacognitive (the awareness of the way in which the knowledge was cognised) aspects in learning.

Types of teaching models

There exists huge variety of teaching models arising from a variety of sources representing different frames of reference towards educational goals. They include historical teaching models, philosophical teaching models, psychological teaching models, teaching models for teacher education and modern teaching models (Aggarwal, 1995; Sharma, 2003). Here an attempt is made to describe the modern models of teaching.

Modern models of teaching

Joyce and Weil (2003) grouped the models of teaching into four families based on their primary emphasis - the way they approach educational goals and means. They are - - (1) information processing family, (2) personal family, (3) social family, and (4) behavioural systems family. Each of the families is discussed below.

1) Social family

The social models of teaching are developed to generate 'synergy' (collective energy generated when people work together). The teaching models of social family or social interaction oriented family aim to develop social efficiency among people. Joyce and Weil emphasise the function of social family of models as they give priority for improvement of democratic processes and the improvement of the society to the improvement of individual's ability (cited in Mangal, 1995). The different models belonging to this family of teaching models are listed below (Joyce & Weil, 2003, p. 13).

	Model	Developers
1	Partners in learning	
	Positive interdependence	David Johnson, Roger Johnson, Margarita Calderon Elizabeth Cohen
	Structured inquiry	Robert Slavin
2	Group investigation	John DeweyHerbart Thelen
3	Role playing	Fannie Shaftel
4	Jurisprudential enquiry	Donald Oliver James Shaver

2) Information processing family

Information processing models emphasise ways of enhancing the human being's innate drive to make sense of the world, by acquiring and organising data, sensing problems and generating solutions to them, and developing concepts and language for conveying them (Joyce & Weil, 2003). Models included in information processing family are helpful for the processing of information. Information processing models are more concerned with the intellectual growth rather than the emotional or social development of the individual. Here the knowledge is acquired while they collect and operate information. The models belonging to this family are categorised as following (Joyce & Weil, 2003, p. 15):

	Model	Developers
1	Inductive thinking (classification-oriented)	Hilda Taba
2	Concept attainment	Jerome Bruner
3	Mnemonics (memory assists)	Michael Pressley Joel Levin Richard Anderson
4	Advanced organisers	David Ausubel
5	Scientific enquiry	Joseph Schwab
6	Inquiry training model	Richard Suchman
7	Synectics	Bill Gordon

3) Personal family

The personal models of teaching begin from the perspective of selfhood of the individual. They attempt to shape education so that we come to understand ourselves better, take responsibility for our education and learn to reach beyond our current development to become stronger, more sensitive and more creative in our search for high quality lives. The models of personal family pays great attention to the individual perspective and seeks to encourage productive independence so that people become increasingly self-aware and responsible for their own destinies (Joyce and Weil, 2003, p. 18). The models belonging to the personal family are listed below:

	Model	Developers
1	Non-directive eaching	Carl Rogers
2	Enhancing self-esteem	Abraham Maslow

4) Behavioural systems family

The various teaching models in this family focus the attainment of self-control, the proficiency to reduce mental strain, to develop leadership qualities and to meet the challenges suitably. These models have their origin in the classical conditioning experiments of Pavlov in 1927, the work of Thorndike on reward learning in 1898, 1911 and in 1913, and the studies of Watson and his associates who applied the Pavlovian principles to the psychological disorders of human beings. It was only in the past three to four decades that behaviour theory (learning) has been systematically applied in school settings. The impetus on these recent applications comes primarily from the works of B.F. Skinner and Wolpe. It can be seen that Skinner's operant conditioning has given birth to most of the models belonging to this family (Sharma, 2003). The different models in this family are listed below (Joyce & Weil, 2003, p. 20).

	Model	Developers
1	Mastery learning	Benjamin Bloom, James Block
2	Direct instruction	Tom Good, Jere Brophy, Carl Gereiter, Ziggy Engleman, Wes Becker
3	Simulation	Carl Smith, Mary Smith
4	Social learning	Albert Bandura, Carl Thoresen Wes Becker
5	Programmed schedule	B.F. Skinner

Description of fundamental elements of a teaching model

A teaching model provides valuable guidelines and blue print for carrying out the task of the realisation of some specific goals. In order to make use of a model, a teacher must be properly acquainted with the knowledge of the fundamental elements of that model.

Generally, a teaching model is described in the context of some fundamental elements. The major elements needed for the description of a teaching model are - - focus, syntax, principles of reaction, social system, support system and instructional and nurturant effects (Mangal, 1995; Sharma, 2003). However, the element focus is not discussed in Joyce and Weil (2003).

1. **Focus:** Focus is the central aspect of a teaching model. For what the model stands, is the theme of the focus. All of the teaching models are meant for achieving some specific goals or objectives of teaching in relation to the environment of the learner. Therefore, objectives of teaching and aspects of the environment generally constitute the focus of the model (Mangal, 1995).

2. **Syntax:** The term syntax refers to the description of the model in action. It describes the sequence of activities in the model - 'how to start, how to proceed and how to conclude.'

3. **Principles of reaction:** This element of the model describes how should a teacher regard and respond to the activities of the students while working out the model. These responses should be quite appropriate and selective. Sometimes, s/he may shape the behaviour of the students by some activities, sometimes avoids the positive reactions from the part of students and in some other cases, teacher adopts passive role allowing students to be self-directive.

4. **The social system:** The social system describes the roles and relationship of the students and teacher. In some models, teacher is the centre of activity; in some others, active participants are students. There are also models in which both the student and the teacher share the activity more or less equally. In the first case, the social system is **highly structured** and can be planned earlier; in the second, the system is **low structured** and in third, it is **moderately structured** or **medium structured**. The role of the teacher varies from model to model and the way in which the student behaviour is rewarded also differs from model to model.

5. **The support system:** The support system indicates the

supporting conditions necessary for the proper functioning of the model. It describes the teaching tools, human skills, capacities and technical facilities used in working out the teaching model.

6. **Instructional and nurturant effect:** This is the element of a model, which describes its application context. Some models are meant for short lessons, some for large and some for both. They also differ in terms of the goal achievements. Each model through its element of application context tries to describe the feasibility of its use in varying context achieving specific educational goals and demanding specific work environment (Mangal, 1995). The applicability of the model produces two effects viz.

   (i) Instructional effect (Direct effect)

   (ii) Nurturant effect (Indirect effect or implicit effect)

Functions and applications of teaching models

1. They suggest the ways and techniques of creating favourable environmental situations for carrying out teaching process
2. They help in achieving desirable teacher pupil interaction during teaching
3. The ultimate goal of bringing desirable changes in the behaviour of pupil may be achieved through these designs
4. They help in the construction of a curriculum or contents of a course
5. They help the teacher to select appropriate teaching techniques, strategies or methods for the effective utilisation of the teaching situations and materials
6. They help in the proper selection of instruction materials for teaching the prepared curriculum or course
7. They are helpful to design the appropriate educational activities
8. They stimulate the development of new educational innovations
9. They help to establish teaching and learning relationship empirically
10. They are useful to develop social, personal and cognitive abilities

Description of selected teaching models

a. Concept Attainment Model (CAM)

Jerome S. Bruner and his associates Jacqueline Goodnow and George Austine are credited for the development of concept attainment model. This model is based on the assumption that human beings are endowed with the capacity to discriminate and to categorise objects and phenomena into groups (Aggarwal, 1995). The concept attainment model helps students to describe the similarities and relationship among things of the environment.

Major ideas behind concept attainment

1. Our environment is full of tremendously diverse things and it is impossible to adjust with it, if one is not endowed with the capacity to discriminate, to categorise things in groups and to form concepts. In order to interpret various things, it is necessary to classify objects or events on the basis of similarities and differences. According to Bruner - - "to perceive is to categorise, to conceptualise is to categorise, to learn is to form categories, to make decision is to categorise." That is, in order to interpret various objects or events, there is a coding system in every individual and a well-structured coding system should be developed in an individual through education.

2. A concept, a generalised mental image, which represents all the members in a particular category. Simply it is an abstraction from facts. Concepts form the basic vocabulary for efficient learning. A concept includes five elements. They are:

   (a) **Name -** is the word that describes a concept for communication, for example, atom, friction, etc.

   (b) **Exemplars -** are the instances or items that could be used in the process of categorisation. They may include positive examples (exemplars) and negative examples (non-exemplars). Items that obey all the essential characteristics used for categorisation leading to the concept are positive examples. Whereas items that do not satisfy all the characteristics of positive example, but are needed for making the grouping meaningful are called negative examples. The knowledge of negative examples is essential because the ability to distinguish positive examples definitely develops only through comparisons with related negative examples.

(c) **Attributes -** are the features or characteristics based on which a number of items could be categorised into a particular group or class that represents the concept. The features that are crucial for the occurrence of the object or event are called essential attributes. Certain others are not to be considered essential and are called non-essential attributes. For example, consider the attributes of concept "metals" - malleability, ductility, lustre, presence of free electrons, etc. are attributes. However, the essential attribute of a metal is the presence of free electrons; others are non-essential.

(d) **Attribute value -** attributes have value and range. The value of an attribute is evaluated or identified based on its role in identifying and defining a particular concept. For example, consider the concept poison. Chlorine is a poison that we put in water. Yet, we judge the amount of chlorine that will kill certain bacteria and still not harm human beings. Therefore, tap water is not an exemplar of poisonous water because it does not contain enough poison to harm human beings. The value of the attribute is low enough; its presence does not give the water membership in the category poisonous to human beings.

(e) **Rule or definition -** is formed from the essential attributes to describe a concept. It is the statement of the meaning attached to a word expression, operation or symbol.

3. Learning is nothing but learning to learn. The learning material and the process of learning are equally important. Effective and the systematic ways of solving problems should be devised, that is, every learner should learn how to learn.

4. Make use of the wonderful gift given to human being by nature - curiosity as the dynamic force leading to discover.

5. Anything can be taught to anybody in any level of development in an intellectually honest manner (Bruner, 1961). Experiences should be selected in accordance with the developmental stages of the learners.

6. The strategy to learn should be discovery learning.

7. Categorising activity has two components, the act of concept formation and the act of concept attainment. In the concept attainment, the concept is determined in advance and the task is to determine the elements of the concept. Concept formation is the act by which new categories are formed; it is an act of invention.

Description of concept attainment model

Based on the ideas put forward by Bruner and his associates, different models of teaching have been developed. They are - - (1) reception model of concept attainment (2) selection model of concept attainment and (3) the model of unorganised material. Each of those models has a slight different sequence of activities (syntax) but all are developed from a common conceptual base. The reception model is described below.

Description of reception model of concept attainment

(1) **Focus -** it is to help the students in the attainment of a particular concept. It also enables them to become aware of the process of conceptualising.

(2) **Syntax -** sequence of the phases and activities in reception model is outlined below

Phase I: Presentation of data and identification of the concept

Activities (i) presenting examples with 'Yes' or 'No' labels in a prearranged order by the teacher

(ii) comparing attributes from positive and negative examples

(iii) generating and testing hypothesis

(iv) stating the rule or definition of the concept according to its essential attributes

Phase II: Testing attainment of the concept

Activities (i) correctly identifying additional unlabelled examples of the concept as 'Yes' or 'No'

(ii) generating own examples

Phase III: Analysis of the thinking strategy

Activities (i) describing thoughts

(ii) describing role of hypothesis and attributes

(iii) discussing type and number of hypothesis

(iv) evaluating the strategies

(3) Principles of reaction

During the flow of the lesson, the teacher needs to be supportive of the students' hypothesis - emphasising, however that they are hypothetical in nature - and to create a dialogue in which students test their hypothesis against each others'. In the later phases of the model, the teacher must turn the students' attention towards analysis of their concept and their thinking strategies, again being very supportive. The teacher should encourage analysis of the merits of various strategies rather than attempting to seek one best strategy for all pupils in all situations (Joyce & Weil, 2003).

(4) Social system

In CAM, the teacher chooses the concept, selects and organises the material into positive and negative examples. The teacher will have to design the material (sequence them) in such a way that the attributes are clear. The teacher acts as a recorder, keeping track of hypotheses (concepts) as they are mentioned and about the attributes. The teacher also supplies additional examples as needed. The three major function of teacher during concept attainment activity are: (1) to record, (2) to prompt (cue) and (3) to present additional data (examples). Thus, generally the social system in CAM is highly structured. A close examination of the syntax proves that the phase one is highly structured, phase two is moderately structured and phase three is low structured.

(5) Support system

Concept attainment model requires appropriate examples and non-examples as the most important support system to facilitate the class. Materials so designed with concepts embedded in it can be used – black board, stuffed materials, etc. Creation of atmosphere for the class is also important.

(6) Instructional and nurturant effects

a. Instructional effects

(i) getting clear notions about the nature of concepts

(ii) developing skills in using appropriate concept building strategies

(iii) attaining the specific concept

(iv) developing skill in inductive reasoning

b. Nurturant effects

(i) sensitivity to logical reasoning

(ii) tolerance of ambiguity and initial errors

(iii) a sense of using alternative perspectives

Unlike reception model, the tracking and analysis of the attributes is quite informal in selection model. The selection model differs from reception model in respect of the labelling of examples. While in reception model all the examples are labelled wheras the selection model requires unlabelled examples with the exception of first two demonstrated in the beginning (Mangal, 1995). The selection model puts more responsibility and demands on the student in comparison to reception model; so this model is more suitable for students at higher level.

The unorganised material model represents third variation in the teaching of concept attainment. It is similar to reception and selection model, but the difference is that except the first two, all other examples are provided by the students; ensuring more autonomy to students. This model is suitable for higher grades (Mangal, 1995).

Merits of concept attainment model

(1) It is a natural way of teaching and learning

(2) It is helpful in developing the power of imagination of the students

(3) It helps in the developments of reasoning power of the students

(4) It helps the students to analyse things systematically

(5) It keeps students actively engaged in the classroom activity

(6) It helps students in making good reasons

(7) It encourages students in the habit of self-study

(8) It helps the learners to apply their knowledge in different situations

(9) It keeps the students busy in the classroom work

A sample lesson plan based on CAM is given in Appendix I.

b. Inquiry Training Model (ITM)

Richard Suchman developed the inquiry training model for developing scientific inquiry skills in pupils. This model is developed for the systematic understanding of the subject matter and to develop various process skills, which leads to new theories and principles. The abilities such as productivity in creative thinking, skills for analysing and collecting information, patience, objectivity, curiosity, intellectual discipline, etc. can be developed through this model.

Major ideas behind inquiry training

Inquiry training originated in a belief in the development of independent learners; its method requires active participation in science inquiry. Suchman summarises the goals of inquiry training model through his theory. His theory is that (cited in Joyce & Weil, 2003, p. 194):

1. Students inquire naturally, when they are puzzled.
2. They can become conscious of and learn to analyse their thinking strategies
3. New strategies can be taught directly and added to the students' existing ones
4. Cooperative inquiry enriches thinking and helps students to learn about the tentative, emergent nature of knowledge and to appreciate alternative explanations

Description of inquiry training model

(1) **Focus**: The focus of this model is to improve the inquiry skills of the children through systematic inquiry training.

(2) **Syntax:** The syntax of inquiry training model consists of five phases. The first phase is the students' confrontation with the puzzling situation. Phases two and three are data gathering operation of verification and experimentation. In these two phases, students ask a series of questions to which teacher replies yes or no and they conduct a series of experiments on the environment of the problem situation. In the fourth phase students, organise the information they obtain during the data gathering and try to explain the discrepancy. Finally, in phase five, students analyse the problem solving strategies they used during the inquiry. The phases and the concerned operations are summarised as follows (Joyce & Weil, 2003).

Phase I: Confrontation with the problem

In phase one, the teacher presents a problem situation and explains the inquiry procedure to students (the objectives and procedure of yes/no question). The discrepant event can be a puzzle, problem, riddle or a magic trick that doesn't require much background knowledge. A discrepant event is the one that entails conflict with our notions of reality.

Phase II: Data gathering – verification

In phase two, students gather information (data) about the event that they see or experience. During this phase students ask questions about - - (1) object, (2) event, (3) condition, and (4) properties. Each type of question is briefly described below.

1. Object questions: Object questions are intended to determine the nature or identity of object. For example, is the bimetal strip made of copper and Iron? Is the compound a hydrocarbon?
2. Event questions: Event questions attempt to verify the occurrence or nature of an action. For example, did the metal strip bend? Did the compound burn in the absence of a compound which is a rich source of oxygen?
3. Condition questions: Condition questions relate to the state of objects or systems at a particular time. For example, did the temperature rise beyond 40^{o}C after an hour?
4. Property questions: Property questions aim to verify the behaviour of objects under certain conditions as a way of gaining new information to help build a theory. For example, does copper bend always when heated?

Phase III: Data gathering – experimentation

In phase three, that is, experimentation, students introduce new elements (variables) into the situation to see if the event happens differently. Experiments have two functions - - explorations and direct testing. Exploration is changing things (adding or deleting a variable or changing a variable quantitatively beyond the known limit) to see what will happen.

The following guidelines will help students while asking questions.

1. Ensure that the questions are phrased in such a way so as to elicit Yes/No response
2. Ask pupils to be specific with their questions
3. Direct pupils' enquiry questions towards objects, events, conditions and property

4. Ask pupils to rephrase the inappropriate questions
5. Encourage interaction among pupils.
6. Provide a free intellectual environment without evaluating pupil's questions.
7. Review the questions and responses to help the students to keep track of the process.

Phase IV: Organising, formulating an explanation

In phase four, the teacher calls on students to organise the data and to formulate an explanation. Students can individually give their explanation and the group can finally shape the explanation that fully responds to the problem situation.

Phase V: Analysis of the inquiry process

In phase five, students are asked to analyse their pattern of inquiry. They may determine the most effective questions and productive line of questioning and the type of information they needed which they may not have obtained.

(3) Principles of reaction: The most important reactions of the teacher take place during the second and third phases. During the second phase, the teacher's task is to help the students to inquire but not to do the inquiry for them. If the teacher is asked questions that cannot be answered by a yes or no, he or she must ask the students to rephrase the questions to further their own attempts to collect data and relate them to the problem situation. The teacher can, if necessary, keep the inquiry moving by making new information available to the group and by focusing on particular problem events or by raising questions. During the last phase, the teacher's task is to keep the inquiry directed toward the process of investigation itself (Joyce & Weil, 2003).

(4) Social system: The social system of Inquiry training model is to develop a cooperative and rigorous environment. Generally, the social system of inquiry training model is highly structured. A close examination of the syntax reveals that the social system is highly structured in the beginning. In phase II and III, it seems to be medium structured and gradually turns to low-structured in phases IV and V.

(5) Support system: The supporting conditions for the effective use of Inquiry training model are:

(i) A really perplexing and challenging problem and an appropriate problematic situation that warrant inquiry

(ii) Technical understanding of the intellectual process and strategies of inquiry

(iii) Resource materials bearing on the problem

(6) Instructional and nurturant effects

(a) Instructional effects

(i) develop skills in inquiry training

(ii) develop strategies for creative thinking

(iii) helps in developing process skills related to science

(iv) promotes active autonomous learning

(b) Nurturant effects

(i) increases creativity

(ii) develops tendency for self-study

(iii) develop tolerance towards ambiguities and difficulties

(iv) promotes co-operative learning

Merits of inquiry training model

(1) It helps in developing the imagination power of the students

(2) It gives training in analyzing things systematically

(3) It helps in developing reasoning power

(4) It provides training to students to raise suitable questions

(5) It gives training to the students for solving various problems of life systematically

(6) It engages the continuous attention of the teacher as well as the

students. Students hardly can afford to be absent minded

A sample lesson plan based on ITM is given in Appendix II.

c. Cooperative Learning Model

Cooperative learning model is a teaching strategy, which allows students to work together in groups with individuals of various talents, abilities and backgrounds to accomplish a common goal. The cooperative learning model operates on the belief that teacher-dominated recitation is actually bad for society. It is based on the philosophy of education that assumes that the aim of education is to provide conditions in which the natural curiosity, intelligence and expressiveness of students will emerge and develop (Kagan, 1992). John Dewey is the dominating figure in the effort to develop models on democratic processes. The proponents of the cooperative model believe that knowledge is constructed and continuously reconstructed by individuals and groups. Robert Slavin, Roger Johnson, Spencer Kagen and several others have investigated the effects of co-operative learning models.

Cooperative learning theorists differ in their views about whether groups should compete with one another. Slavin favoured competition whereas Johnson favoured co-operation. It is also encouraging to note that students with proper academic histories benefit quickly. Partnerships increase involvement, and the concentration on co-operation has the side effect of reducing self-absorption and increasing responsibility for personal learning. There is evidence to prove that even gifted students perform well in cooperative learning environments.

Tasks that require social interaction will stimulate learning. The belief about cooperative learning is that cooperative behaviour is intellectually stimulating.

Major ideas behind cooperative learning model (Joyce & Weil, 2003)

1. The synergy (collective energy) created in co-operative settings of learning generates more motivation than individualistic and competitive environments. Integrative social groups are, in effect,

more than the sum of their parts. The feelings of connectedness produce positive energy.

2. The members of cooperative groups learn from one another. Each learner has more helping hands than in a structure that generates isolation.
3. Interacting with one another produces cognitive as well as social complexity, creating more intellectual activity that increases learning when contrasted with solitary study
4. Cooperation increases positive feeling towards one another, reducing alienation and loneliness, building relationships and providing affirmative views of other people
5. Cooperation increases self-esteem, not only through increased learning but also through the feeling of being respected and cared for by the others in the environment
6. Students can respond to experience in task requiring cooperation by increasing their capacity to work productively together. In other words, the more children are given more opportunity to work together, the better they get at it, which benefit their general and social skills.
7. Students, including primary school children can learn from training to increase their ability to work together

Cooperative learning environment

The classroom is analogous to the larger society. It has a social order and a classroom culture. Students care about the way of life that develops in the classroom and the standards and expectations that become established. The normal classroom order that develops around the basic values of comfort and politeness or keeping the teacher happy is rejected in this model. The classroom group develops a social order towards a series of inquiries.

The group size can be two to six; however, groups larger than six students require skilled leadership. Students should be trained for working with efficiency in groups, in addition, they should be trained to become truly interdependent. Procedures to take turns and to assume responsibilities will improve interdependent behaviours among group members. A variety of procedures has been developed to help students learn how to help one another by dividing labour.

Description of cooperative learning model

(1) Focus: The focus of cooperative learning model is to build the social skills among students. It includes leadership qualities, decision-making abilities, communication skills, trust building, conflict management, etc.

(2) Syntax: The syntax of cooperative learning model consists of six phases. The sequence of the phases in this model is outlined below

Phase I : **Students encounter a puzzling situation** (planed or unplanned)

Phase II : **Students explore reactions to the situation**

Phase III : **Students formulate study task and organise for study** (problem definition, role-assignments, etc.)

Phase IV : **Independent and group study**

Phase V : **Students analyse progress and process**

Phase VI : **Recycle activity**

(3) Principles of reaction

The role of the teacher is one of counsellor, consultant, and friendly critic. The teacher must guide and reflect the group experiences over three levels - - (1) task level, (2) group management level and (3) the level of individual meaning. The instructor must facilitate group processes, intervene in the group to channel its energy into potentially educative activities, and supervise these educative activities (Joyce & Weil, 2003).

(4) Social system

The social system is democratic, governed by decisions developed from or at least validated by the experiences of the group directed towards the objectives of the study. The groups plan the activities. Students and teacher have equal status except for role differences. The atmosphere is one of reason and negotiation (Joyce & Weil, 2003).

(5) Support system

The support system includes a well-stocked library in the institution and liaison with outside resources as well.

(6) Instructional and nurturant effects

a. Instructional effects

(i) it promotes constructivist view of knowledge and its reconstruction

(ii) independence in learning and respect for the dignity of others are well recognised

(iii) it encourages disciplined inquiry, effective group process and governance

b. Nurturant effects

(i) respect for dignity of all and commitment to pluralism

(ii) independence as a learner

(iii) commitment to social inquiry

(iv) interpersonal warmth and affiliation

Merits of cooperative learning model

(1) It increases group cohesion as the team works to learn information or skills while ensuring that all members have both responsibility for learning and an important role in the group

(2) It is highly versatile and comprehensive

(3) It blends the goals of academic inquiry, social integration, and social process learning

(4) It is based on the view of knowledge and it reconstruction

For many students, knowing that they would share what they have learned with other students appeared to be far more powerful motivational device than traditional letter grade (Kagen, 1992).

Cooperative learning is philosophically linked to group investigation, which places faith in curiosity, intelligence, and expressiveness of students rather than in extrinsic points and competitive motives. The aim of education is to provide conditions in which the natural curiosity, intelligence, and expressiveness of students will emerge and develop. Traditional approaches, which assume that the student is void into which educators must pump facts, theories, and methods. Students learn in order to satisfy their own curiosity about themselves and the world and to share with others. Students are encouraged to discover and express their own interest in the subject covered. The progress in learning is not toward a pre-determined teacher defined goal; it is a process that flows out of the interests of the students.

Chapter V

SCIENTIFIC METHOD

Scientific method is a method, used for solving problems scientifically. It is also referred to as 'the method of science' or 'the method of a scientist.' Sometimes it is called 'problem solving method.' Scientific method is essential in the study of science. Scientific method is used to standardise knowledge, which is considered 'standard' at that time. This is because the scientific knowledge itself is quite tentative in its character. While tracing the history of physics we can see where father (J. J. Thomson) and son (George Thomson) received Nobel prizes in 1906 and in 1937 for proving two opposite views on the same subject - - the particle nature and wave nature of electrons (Vaidya, 1971). This is because the fundamental ideas of science change in the course of time.

Fields defined scientific method as "the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experimentation, the formulation of a hypothesis, and the testing and confirmation of that hypothesis" (cited in Martin, Sexton, Wagner, & Gerlovich, 1997, p. 311).

According to Lundberg, "scientific method consists of systematic observation, classification and interpretation of data." According to Karl Pearson, "the scientific method is marked by the following features - (1) careful and accurate classification of facts, (2) observation of their correlation and sequence, (3) discovery of scientific laws by the aid of creative imagination, their self criticism, and (4) the final touch-stone of equal validity for all normally constituted minds" (cited in Mangal, 1990).

The scientific knowledge acquired through scientific method is not static and is subject to change on further verification. The acquired knowledge must be consistent with what we 'know' about the world and it should be testable. The scientific method combines both empirical evidence and the creative interpretation of data by scientists. The outcome of scientific investigation is not totally objective as it is the product of both observation and inference.

Steps in Scientific Method

There is no single set or sequence of steps in a scientific investigation. In order to make use of scientific method, students should be taught and well trained in the method of attacking a problem. Different scientists adopt different methods for solving a problem in hand. If a pre-planned procedure is used, they can understand the problem clearly. Mills and Dean suggested six steps for scientific method (cited in Vaidya, 1971). They are:

(1) Problem survey - analysing a potential problem situation for, item to be studied

(2) Problem description - providing a clear statement for item to be studied

(3) Problem discussion - making sure that the student understand what is involved in the problem

(4) Problem limitation - isolating those part of the problem that can be attacked profitably

(5) Planning for action - preparing suitable hypotheses for investigation

(6) Further analysis and limitation - tentative testing of hypothesis to identify those most likely to yield solution

Karl Pearson gave scientific method its modern form. The following are the major steps of the scientific method (cited in Mangal, 1990).

(1) Sensing the problem including its definition, scope and analysis

(2) Experimentation

(3) Collection of data, interpretation of data, selecting and examining the most fruitful hypothesis and arriving at a tentative solution

(4) Establishment of the law

(5) Generalisation of the law (theory)

(6) Application of the law to new situations

(7) Predictability

(8) Idealisation and abstraction

In scientific method, the investigator has to move through various steps that are indispensable in the scientific endeavour. Joseph (1982) listed the following five steps for scientific method.

(1) A felt difficulty

(2) Defining and locating the problem

(3) Suggestion of probable solutions (Formulation of hypotheses)

(4) Finding out the bearings of the solution

(5) Further observation and confirmation through experiments

Each of these steps is described below.

1. A felt difficulty

Sensing a problem from a given situation or previous experience is the first. Teacher should accept the problem selected by the students giving due consideration to its suitability to the curriculum, availability of data, utility to the students in promoting scientific talents, interest of students, possibility of group work and development of reflective thinking. This step must be a co-operative endeavour of both the teacher and the students.

The following example illustrates the first step in scientific method. A cylindrical coil of insulated wire is taken and the ends of the wire are connected to a small bulb, now a bar magnet is rapidly introduced into the coil. It is kept inside the cylindrical coil for some time and then it is rapidly withdrawn. The students observe that the bulb glows only when the magnet is introduced or withdrawn, but it does not glow when it is stationary inside the coil. The following questions may be asked to the students:

1. Why does the bulb glow, when the magnet is introduced inside the coil?
2. Why does the bulb glow, when the magnet is withdrawn from the coil?
3. What is the source of current due to which the bulb glows?
4. Why does the bulb not glow when the magnet is stationary inside the coil?
5. Why does the bulb glow for a short period only?

The students develop an inner urge to find out the answers to the above said questions.

2. Defining and locating the Problem

The problem should be studied and analysed thoroughly from all possible angles. In this step questions such as 'what is the problem', 'how can it be solved', etc. should be given serious consideration. In the light of such questions, the problem should be defined clearly in a concise, precise and clear language. Need and significance of the study with its scope and limitations should be made clear. There should be some key words in the statement of the problem which may help in better understanding of the problem. The students should be asked to write down the statement of the problem and submit for classroom criticism and discussion. The most appropriate statement should be accepted. In the example illustrated above the statement of the problem may be like:

1. Study of the source of current in the coil when a magnet is introduced into it
2. Study of the source of current in the coil when a magnet is withdrawn from it

3. Study of the reason why the current produced in the above cases is only for a short period of time
4. Study of the reason why there is no current when the magnet is stationary inside the coil

3. Suggestion of probable solutions (Formulation of hypotheses)

Through analysis and synthesis, methodical inference and imagination several hypotheses or suggestions of probable solutions are arrived at. All available hypotheses are taken into consideration without prejudice or personal bias. For example, the students note down the key words and phrases in the stated problem which furnish clues to its solution. In the above problem, the key words are "source of current" when "magnet is stationary inside the coil" and that the "current is only for a short time." These words, phrases or sentences give a clue to the formulation of hypotheses. The formulated hypotheses should satisfy the following conditions:

1. It should agree with the needs of the problem
2. It should be in tune with the pre-established facts and principles
3. Its validity can be checked by further verification either by testing its workability in similar situations or by proving its non-workability in negative instances

4. Finding out the bearings of the solution

The implications of each hypothesis are reasoned out logically and tested through further observation and experiments. If the implications (bearings) do not agree with the observed facts they are rejected, otherwise accepted.

5. Further observation and confirmation through experiments

The most important characteristic of the scientific method is the tendency to inhibit rash and baseless judgements. Conclusions are subjected to rigorous (repeated) tests.

The students should apply their generalization to their daily life. This will bridge the gap between the classroom situation and real life situation. Thus, a generalisation derived through scientific method cannot be regarded as an accepted conclusion unless it possesses sufficient ground for solving similar circumstances. Moreover, the application of the principle will help in verifying the principle itself. Thus, scientific method derives a definite procedure for solving the problem inductively and subsequently testing the adequacy of the generalisation deductively.

Characteristics of Scientific Method

The important characteristics of scientific method can be enumerated as follows:

1. Scientific method is characterised by objectivity and definiteness in its process as well as product
2. Scientific method provides enough training in information processing and drawing conclusions
3. The results derived from the scientific method show generality
4. The results obtained by this method are characterised by the ability of predicting the future outcomes of the objects or events
5. Peculiarities of the outcomes of scientific method are their modifiability and dynamicity

Processes Involved in Scientific Method

Every scientific investigation involves two kinds of processes - 1) the logical process and 2) the technical process. The technical operations may vary but the logical process of drawing conclusions from data is common to all sciences. Although technical processes are indispensable in most scientific enquiries, they are only to assist in the successful performance of the different steps in the logical process. The logical process is not different from the thought process by which we solve problems of daily life. The difference is only in the complexity of the problem and in the degree of perfection of the solution. The logical processes include induction, deduction, analogy, analysis and synthesis and testimony and authority. The technical process includes collection of data, observation, experimentation, measurement and manipulation. The logical process is more important than the technical process because it is in the minds of scientists that propositions originate.

Elements of Scientific Method

In drawing inferences, several processes are made use of. The important logical processes that will be discussed here include - - induction, deduction, analogy, analysis and synthesis, and testimony and authority. Each process is detailed below.

I. Induction

Induction may be defined as the "operation of discovering and proving general propositions" (Mill, 1949, p. 186). It is the operation of the mind by which we infer what we know to be true in a particular case or cases will be true in all cases which resemble the former in certain assignable respects. Thus, induction is a process of inference: it proceeds from the known to the unknown (Mill, 1949, p. 188). It is through induction that we arrive at inter-relation among natural phenomena, generalization, laws and principles.

The renowned philosopher Francis Bacon (1561-1626) suggested inductive reasoning (Ozmon & Craver, 1986). He severely criticised the practice of deductive reasoning. Induction can be classified into three - - **(1) Perfect induction (2) Baconian induction** and **(3) Imperfect induction** (Van Dalen, 1962, pp. 21-23). Perfect induction involves analysis of all cases in a class or group under consideration. It cannot be employed for practical reasons. In Baconian induction the investigator should study nature closely and establish general conclusion based on his/her direct observation. Positive instances, negative instances and cases in varying degrees should be examined to make a valid conclusion. In imperfect induction, some cases that make up the class or group are examined to arrive at a conclusion. This is the method followed in most of the investigations. All inductive inferences are based on two laws - - (1) The law of uniformity of nature and (2) The law of causation.

1. The law of uniformity of nature

A phenomenon that takes place in certain circumstances will repeat itself whenever the same circumstances occur. That is, nature is uniform in her behaviour.

2. The law of Causation

Nothing takes place by sheer chance. Every phenomenon has a cause or a set of causes invariably connected with it.

In complex cases, when there is a plurality of causes, it is difficult to decide which is the cause and which is the effect. In such cases, we adopt one of the following five methods known as Mill's canons of induction. John Stuart Mill is the first among several others to provide the most systematic analysis of causation, which are presented in the five canons (Mill, 1949; Van Dalen, 1962; Mouly, 1964).

The five canons are - - (1) Method of Agreement, (2) Method of Difference, (3) Joint Method of Agreement and Difference, (4) Method of Residue, and (5) Method of Concomitant Variations. In establishing the causal relationship and arriving at an inductive inference, Mill's canons are made use of. The cause of a phenomenon is the totality of the circumstances indispensable to its occurrence. In other words, if other conditions remaining the same, a certain circumstance cannot be omitted or quantitatively changed without changing a certain phenomenon, then that circumstance is the cause of the phenomenon.

a. Method of Agreement

"If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon" (Mill, 1949, p. 255). If in every observed instance of a phenomenon, only one circumstance is common that circumstance is probably a cause or condition of that phenomenon.

Van Dalen (1962) presents a concrete illustration to make the method more comprehensible. Suppose that six students – A, B, C, D, E and F – went to a debating tournament and subsequently three of them – A, B, and C – became ill. To find out the cause of their illness, the doctor might question A, B and C about what food they had eaten and find that every item they had selected differed except for strawberry cream pie. In other words, the only food consumed by all those who became ill was the pie (Van Dalen, 1962, p. 201).

The conclusions drawn by this method are not decisive and unless a good number of varied circumstances are considered and all other causal circumstances are eliminated, the method may lead to absurd conclusion. The difficulty in finding out common circumstances and inadequate analysis of complex circumstances also cause failure in reaching conclusion.

b. Method of Difference

"If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one (except one), that one occurring only in the former; the circumstance in which alone two instances differ is the effect, or the cause, or an indispensable part of the cause of the phenomenon" (Mill, 1949, p. 256). Whenever the elimination of a single circumstance is accompanied by the non-occurrence of a phenomenon, that circumstance is probably related to its causation.

For example, if a surface exposed to air is dry at the atmospheric temperature and it becomes wet on lowering its temperature while other conditions remain unaltered it may be concluded that lowering of temperature is the cause for the wetness of the surface.

This method is largely used in experimental sciences as well as in every day life. In this method, we compare two circumstances one in which the phenomenon occurs and the other in which it does not. It is very important that the two cases should differ only in one relevant circumstance.

c. Joint Method of Agreement and Difference

"If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance, the circumstance in which alone the two sets of instances differ is the effect, or the cause, or an indispensable part of the cause of the phenomenon" (Mill, 1949, p. 259). If in a group of cases in which a phenomenon occurs and there is one and only one common circumstance, while in another group of cases in which the phenomenon does not occur and there is nothing in common except the absence of the above circumstance, then the phenomenon is causally related to that circumstance.

This is a combination of the two previous methods. The suggestion of causation arrived at by the method of agreement is strengthened by the method of difference. To apply this method in the above example, the doctor would have to determine not only that strawberry cream pie was the only food that all the students with illness consumed, but he also would have to question members of the groups who did not become ill – D, E and F. If he found the only item common to those who suffered no ill effects was the absence of pie, he would have strengthened his conclusion that strawberry cream pie was causally related to the illness of the students. Thus, this method gives the researcher a double check of his conclusions concerning causality (Van Dalen, 1962, p. 202).

d. Method of Residues

"Subduct from any phenomenon such part as is known by previous inductions to be the effect of, and residue of the phenomenon is the effect of the remaining antecedents" (Mill, 1949, p. 260). In other words, if part of a complex phenomenon is known to be causally related to certain operating circumstances, the residual part of the phenomenon must be due to the rest of the circumstances known or unknown. This method suggests how we might obtain a complete knowledge of a complex phenomenon part of which is already accounted by its known causal relationship in certain circumstances. The unexplained residual part must be due to causes, which may or may not be known.

For example, the density of atmospheric nitrogen (separated from liquefied air) in comparison with that of chemically prepared nitrogen, was found to be different and this finding led to the discovery of the element argon in atmosphere.

e. Method of Concomitant Variations

"Whatever a phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation" (Mill, 1949, p. 263). That is, if two phenomena vary concomitantly, while all other relevant circumstances remain unchanged, they must be causally related.

For example, the change of volume of a given mass of gas is observed to be accompanied by a change of temperature as well as a change of pressure. To decide which of them is the cause or whether both of them are independent causes it is not possible to eliminate either. However, each of them might be kept constant and the other varied. The observations thus made reveal the concomitant variation of pressure and volume as also of temperature and volume. Hence, it is concluded that both pressure and temperature are causally related to volume. Accurate measurement of variations of pressure and volume (temperature being kept constant) and mathematical calculations based on them led to Boyle's law. Similarly the measurement of change in temperature and volume (pressure being kept constant) led to Charles law.

The concomitant variation may be of two types - - direct and inverse. When the antecedent and the consequent increase or decrease together, it is said to be direct; when one of them increases as the other decreases the variation is inverse. For example, gravitation between two bodies varies directly with their masses and inversely with their distance from each other (Joseph, 1982).

The above methods suggested by Mill should not be considered as infallible. Difficulty arises when a plurality of causes is present or when different effects remain mixed up in an indistinguishable manner.

II. Deduction

Probably, the first major contribution to the systematic discovery of knowledge was made by the Greek philosopher Aristotle, who perfected the syllogistic method of deductive reasoning (Mouly, 1964,

p. 18). Deduction is the process of reasoning that starts from an accepted generalisation and moves toward a conclusion relating to any specific instance. To legitimate syllogism, it is essential that there should be three, and not more than three, propositions, viz. the conclusion or proposition to be proved, and two other propositions called premises, which together prove it. Syllogisms are divided by some logicians into four according to the position of the middle term which may either be the subject in both premises, the predicate in both, or the subject in one and the predicate in the other (Mill, 1949). Only one type is detailed here. For example,

(i) All A is B; All B is C. Therefore, all A is C

(ii) All men are mortal (major premise); All kings are men (minor premise). Therefore, all kings are mortal (conclusion)

(iii) All metals are good conductors of electricity (major premise); copper is a metal (minor premise). Therefore, copper is a good conductor of electricity (conclusion)

In categorical syllogisms as above, two supposedly true statements stand in such a relationship that they logically imply a particular conclusion. The truth of deductive inference depends on the accuracy of the general proposition (major premise) on which it is based.

Deductive reasoning is a useful tool to employ in problem solving, but it does have limitations. Deduction relies on verbal symbols, which can be quite ambiguous. The same words do not mean the same thing to all people and at all times. For example, health in early days referred only physical fitness, now health means mental and social well-being. Because of the shift in meaning of words, it is often difficult to evaluate an argument. One of the major weaknesses of the method is that it can only deduce the consequences of pre-existing knowledge. It does not probe beyond that which is already known. It is a device for pursuing the consequences of generally accepted statements rather than an instrument to gain new knowledge.

III. Analogy

Scientific method makes use of analogy in drawing inferences in scientific investigations. It is the most primitive type of inference.

Whenever we perceive a new object or an event, the first impulse of the mind is to compare and to connect it with the nearly similar previous experience. When two objects or phenomena are similar in some respects, we anticipate that they would be similar in some other points as well. The recognition of such analogy is often helpful in understanding new experiences and suggesting causal relations. In fact, the first insight into the nature of an apparently new object or phenomena is commonly obtained by analogy (Joseph, 1982, pp. 90-91). General notion of analogy is that it is a relation of resemblance between two objects. The resemblance is a feeling, which in turn is a state of the consciousness of the observer. "When we say that one body is like another we mean that there is a resemblance between the sensations excited by the two bodies, or between some portions of those sensations" (Mill, 1949, pp. 44-45).

Analogy consists of an organised system of symmetrical relations based on identities of parts of structures. Mere similarity of shared features by two objects cannot possibly account for an analogy (Johnson-Laired, 1989). For example, consider the analogy between the solar system and Ruther Ford's model of the atom. The structure of the solar system with sun at the centre and planets at the orbits correspond to the structure of atom with the nucleus at the centre and electrons at the orbits. Moreover, relational features like planets revolving around the sun, planets rotating on their own axis, and fixed orbits of rotation are relational features that hold good in the structure of atom. Thus, analogies draw inference from only one known instance to another (Agassi, 1964). Hence, analogical reasoning is different from inductive and deductive reasoning.

A number of outstanding scientists have profitably used analogies in systematic research and in developing hypotheses. For example, the kinetic theory of gases was modelled on macroscopic elastic spheres such as billiard balls; Huygens developed wave theory of light with the familiar view of sound as a wave; and Fourier's theory of heat conduction was constructed on the analogy of flow of liquids (Nagel, 1961).

A common problem with learning science concept is that their attributes are not observable or imageable. To make the attributes of a concept more perceptible and amenable to concrete operation, scientists have widely used analogies. Analogies provide a viable medium, a vehicle and a meaningful context to process information (Royer & Cable, 1976). That is, an analogy evokes certain effects in the mind of learner, which facilitates thinking about a new idea. Analogies provide comparisons, which can be used to explain difficult-to-understand concepts by pointing out their similarities to something easier to understand, or already understood (Zeitoun, 1984). For example, the structure of a human eye can be compared to the analogue camera. The lens, retina, eye-lid, lens accommodation, pupil dilation and inverted image have comparable elements in camera. Thus, an analogy assists a novice to acquire knowledge and to develop a strategy to deal with new ideas.

IV. Analysis and Synthesis

Analysis and synthesis are the real foundations of scientific method. Analysis is the process of ascertaining the constituents of a system or an entity. In induction we analyse the observed facts of nature into their various component elements and synthesise some of them to formulate inter-relations or a unified whole. In education also, we analyse the implications of a general proposition and synthesise the relevant aspect to obtain a particular truth. Analogical inference also involves analysis of analogous phenomena and synthesis of particular elements.

Things and events of nature are mostly complex and we have to analyse them before we can discover any order or cause-effect relationship. Synthesis helps us to develop class concepts and formulate definitions, discover causal relationship, confirm hypothesis and laws. Analysis and synthesis are particularly important in the study of phenomena having plurality of causes such as cancer and coronary artery disease.

V. Testimony and Authority

Testimony means personal or documentary evidence or attestation in support of a statement or fact. Authority refers to the right to command or give an ultimate decision. Bertrand Russell observed that, to modern educated people (it seems) matters of fact have to be ascertained by observation and not by consulting authorities (cited in Mouly, 1964, p. 20). This is an entirely modern conception, which hardly existed before the 17th century.

When searching for knowledge, man sometimes seeks the testimony of experts, who because of their intellect, training and experience or aptitudes are better informed than other people. Society would not advance if it were unwilling to accept the opinion of specialists. However, one must exercise discrimination while selecting experts. Although it is often necessary to consult experts, it is dangerous to accept their opinion unconditionally and for all time.

Historical records reveal that through out the centuries society has collected not only wisdom but also much intellectual nonsense. Many long-revered educational, medical and scientific theories have been proved false. For example, it was believed that 'aspirin' which is used to lower body temperature has side effects but now doctors say that a calculated amount of aspirin is good because it will minimise the chances of heart diseases.

When one has not had personal experience with a phenomenon, the simple alternative is to consult his/her parents, teacher or even older siblings for answers to problems with which they are not familiar. Throughout the history of science, certain persons have been recognised as authorities. That is, there emerged a group (or class) of people who are credited with having many of the answers to the problems that perplexed their less enlightened contemporaries. Frequently it so happened that these authorities were merely persons of authority or power whose word was law, not because of any great wisdom or communion with truth but because of prestige derived through strength, birth, wealth, association with magic, or some other form of public acceptance (Mouly, 1964, p. 15).

VI. Hypotheses

Hypotheses are tentative suppositions taken as true in the pursuit of scientific investigation. They are calculated guesses that are the products of gifted and informed minds. There are several definitions available in the literature that helps to understand the value and function of a hypothesis.

"Hypotheses are simply inferences that people want to test" (Gega & Peters, 1998, p. 94). According to Hodnett, "Hypotheses are your eyes as you try to approach problems in a scientific manner. Through them you look into the disorder that is a problem and see the possibilities of order" (cited in Van Dalen, 1962, p. 130). In the words of Van Dalen, "A hypothesis serves as a powerful beacon that light the way for the research worker" (cited in Mouly, 1964, p. 88). According to James Creighton, "Hypothesis is tentative supposition or provisional guess, which seems to explain the situation under observation" (cited in Rajan, 1999).

Importance of hypothesis in scientific thinking

Hypothesis plays an important role in scientific investigation. Critical examination of the observed facts and its careful and purposeful reflection (thought) lead to suggestions of probable solutions. These tentative suggestions are known as hypotheses. In a scientific investigation, a hypothesis usually takes the form of a universal relationship in terms of which we attempt to explain the facts of observation. A hypothesis is essentially a product of constructive imagination. As such, it may or may not be a faithful picture of reality. However, without some such suppositions, it is not possible to make any progress in scientific enquiry. Analogy and simple methods of induction are helpful in framing hypothesis. Depth of knowledge, imagination and genuine interest in the subject help in framing fruitful hypothesis.

A hypothesis can be accepted only when it is proved to be in agreement with all relevant facts. Hence, every hypothesis should be subjected to rigorous tests before it is accepted or rejected. In general, we must deduce the implications of the hypothesis. That is, we anticipate such phenomena through suitable experiments. If the results agree with the deduced anticipations, the hypothesis is likely to be true. However, the testing must be repeated by fresh deductions and more extensive observations before it can be accepted as theory or law. When the conclusions drawn from the hypothesis do not agree with the observed facts, it must be modified or rejected. For example, Kepler rejected 14 hypotheses before establishing the laws of planetary motion.

Characteristics of a good hypothesis

A good hypothesis should be legitimate. Legitimacy of a hypothesis has to be ascertained first before it can be used as a guiding device for conducting a scientific enquiry (Majumdar, 2005). The characteristics of a good hypothesis can be enumerated as:

1. It must be conceptually clear, specific, definite and verifiable
2. It must be consistent with well-established laws of nature
3. It must be adequate to explain all the facts under investigation
4. It should be related to available techniques
5. It should be related to a body of theory
6. The consequences of which can be deductively inferred and compared with facts

Before we accept a hypothesis, it must be shown to agree with a particular fact (for which it is suggested). A good hypothesis will be not only in agreement with the already observed facts but also enable us to anticipate other facts, which might be verified by further observation and experiment. The success of a scientific investigation depends on the formulation of a good hypothesis, without the guidance of which we shall not know what to do or observe or what experiment to perform.

Sources of hypotheses

There are a few, more or less clearly defined sources, which the researcher usually would tap for obtaining a general guideline for his/her research (Majumdar, 2005). They are:

1. Hypotheses originate from the existing literature
2. Hypotheses originate from the general culture
3. Hypotheses originate in the science itself
4. Hypotheses originate from analogies

5. Hypotheses originate as consequences of personal, idiosyncratic experiences

Technical Processes of Scientific Method

Apart from the logical processes discussed above, the scientific method draws much from the technical processes such as collection of facts and data, observation and experimentation. Each process is detailed in the following pages.

I. Collection of facts and data

The starting point in any scientific investigation is collection of facts relating to the problem at hand. To scientists, facts are any experience, change, occurrence or event that is sufficiently stable and supported by enough evidence to be counted on in an investigation. To the scientist, facts are not something that is self-evident, but rather data she/he discovers through purposeful probing. To the investigator facts are never permanent or final; they may undergo change as an investigation evolves. They are subject to reinterpretation or revision whenever man gains a better insight into the phenomena.

Facts relate exclusively to objective world, that is, the phenomena of the external universe. They are different from ideas. All knowledge is primarily derived from facts; hence, the collection of facts is very important in a scientific study of any phenomenon. Facts are necessary not only to help us frame hypothesis but also to test them. Facts collected should be accurate, impersonal and extensive. The validity of conclusion ultimately depends on careful collection of facts.

II. Observation

Observation means prolonged perception of things. Every statement of facts or data rests directly or indirectly on observation. Observation may be regarded as the sole process by which we gather facts. Though explicitly a sensory process, observation also implies an almost unconscious inferential process. Observation involves mental processes such as attention, selection, analysis, classification, etc.

Ordinarily observation in a scientific investigation must be purposeful, and then only we will be able to know what to look for and how to look for it. With reference to the problem at hand, we should select and isolate what we have to observe and our attention should not be distracted; if the observation is to be accurate and fruitful. Since inferences and judgements form inevitable part of observation, it is important that observation should be free from bias and prejudice, because human frailties and biases can introduce errors into data gathering.

A scientist often employs movie cameras, recordings, oscillographs or similar instruments to make a permanent record of the occurrences in an investigation. These instruments provide first-hand evidence that s/he and others can study immediately and can recheck as often as necessary in the future. Even the most expensive and delicate instrument do not have the varied powers of observation of human beings. Moreover, instruments are of little value unless the investigator knows how to use them skilfully understands their limitations and checks their operational performance for precision and accuracy.

A successful observer must have an abundance of pertinent previous knowledge. To increase the range, richness and accuracy of observations and to guard against errors in perception, a broad background in the field where in the problem lies is of unique importance. Becoming thoroughly familiar with what to expect in a given situation, places the investigator in a better position to spot significant events that occur as well as any condition that is unusual or that do not conform to his/her belief or accepted theories. It is his/her previous knowledge that enables him/her to select and isolate the features of observation. Correct interpretation is possible only if one has the requisite knowledge.

To avoid errors in perception that arises because of faulty recall a researcher records his/her data soon after observing, in an exact system of notations. Scientific descriptions are written in precise and concrete terms. One employs words and symbols that mean the same thing to other investigators as they mean to the writer. Whenever possible, an investigator describes his/her data quantitatively in terms of height, weight, distance, duration, speed or number of units. Numerical measures are more precise than word description and may make possible further analysis of problem by statistical procedures. It should be noted that the word description and qualitative (ethnographic, anthropological) studies are highly useful in social science but cannot be used profitably in physical sciences.

Observation is subject to error and limitation because of imperfections of human senses. Moreover, sense organs are easily misled because their powers are limited. In addition, the instruments that we use to aid our senses have their limitations too. Therefore, what we can possibly learn by observation is only a fraction of what might really exist.

III. Experiment

Natural phenomena are so complicated that it is often difficult to establish relationship by bare observation. In such cases, one controls the conditions of the phenomena under investigation and observes the results of the control in order to decide causal relationships. This type of artificial observation of phenomena under controlled condition is known as experiment.

Experiment is active observation. In bare observation, we merely note, and record the phenomena as they occur in their natural course. However, in experiment, one study phenomenon, taking place under purposefully pre-arranged condition. The use of instruments does not make the observation experimental in character. They only aid the senses and do not interfere with the observed phenomena, but when we apply a chemical reagent to an object, under microscope, and study the effect, it becomes an experiment.

In an experiment, there are mainly two types of variables - - **(1) the independent variable** and **(2) the dependent variable.** The independent variable is the variable that is altered or manipulated by the investigator. The variable upon which the effects of the change are observed is the dependent variable. For example, a particular method of teaching can be an independent variable and the achievement can be the dependent variable.

Suppose that an investigator wants to determine whether children will achieve greater mastery of the topic "universe" if taught using "computer assisted instruction" or "radio lesson", s/he may select two groups of subjects who are alike in all respects, so that differences in their nature cannot affect the results. However, if s/he fails to control the procedures, differences in them may contribute to the subject mastery of "universe." S/he should provide "computer assisted instruction" and "radio lesson" groups the same treatment, (distribution of practice, equally interesting and difficult lessons, subject matter equally suitable for teaching by either method, achievement test that is equally fair for evaluating both methods of instruction, same amount of time to complete the final tests, etc.) so as to avoid influence of procedural differences on the gains in achievement.

Limitations of Experiments

1. Experiments are not always possible. For example, astronomical phenomena, evolution, earthquake, volcano, etc., are beyond human control and we study them only by observation.
2. Variation of one condition (variable) at a time is not always possible, because in most cases conditions are interdependent.
3. Some conditions are incapable of elimination and others incapable of variation except within certain limits. For example, gravitation, friction, etc.
4. At times, we are lead to erroneous conclusions because of unsuspected conditions influencing the result.

Process Skills Involved in Scientific Method

A number of process skills are involved in the use of problem solving or scientific method. Process skills are part of a chain of activities to collect evidence and to reach valid inferences through an analysis of the same. It focuses on a scientific procedure of developing new knowledge and learning on ones own. American Association for Advancement of Science (AAAS) has identified eight basic skills and five integrated processes (cited in Vaidya, 1971).

I. Basic skills

They are the process skills, which can be emphasised at the primary grades, and serve as a foundation for using the integrated skills at the higher grades. They are the primary ways of obtaining information. The important basic skills are discussed below.

a) Observing

The process of observing is the taking in or sense perceptions. Observing involves using five senses to find out about objects and events, their characteristic properties, differences, similarities and changes.

b) Measuring

Thinking about properties in a quantitative way naturally leads to measuring them. This involves comparing an unknown quantity with a known. The observations are quantified using proper measuring devices and techniques. Here, measurements are to be recorded in an orderly and systematic fashion with labelled units of measure. Charts, graphs or tables can be generated manually or with computer software.

c) Using space time relationship

It refers to observation of form, distance, motion, speed, directions and time. This skill originates from the ability to identify shape of the bodies, their motion, speed and direction.

d) Communicating

It refers to the use of written and spoken words, graphs, demonstrations, drawings, diagrams or tables to transmit information and ideas to others. To reflect the true nature of science, ideas must be shared.

e) Classifying

It refers to the process of organising observations in ways, which carry special meaning. It is the grouping or ordering subjects or events according to similarities or differences in properties. Here lists, tables or charts are generated.

f) Predicting

To predict is to forecast a future observation by inferring from data. It is the process of forming an idea of excepted results. It refers to types of thinking that require our best guesses based on the information available to us (Martin, et al., 1997). It is an insight of what will occur based on present knowledge and understandings, observations and inferences.

g) Using numbers

This means applying number and their mathematical relationships to make decisions. Numbers are basic to science. Mathematical knowledge is applied here.

h) Inferring

It is the process of interpreting or explaining observations or experiences. Inference leads to conclusion. The accuracy of our inferences usually improves with more chances to observe (Gega & Peters, 1998).

II. Integrated process skills

Integrated science process skills rely on the learners' capabilities to think at a higher level and to consider more than one thought at a time. The important integrated process skills are discussed below.

a) Controlling variables

It refers to manipulating one factor to investigate the out come of an event while other factors are held constant.

b) Interpreting data

Interpreting data involves organising, analysing and synthesising data using tables, graphs and diagrams to locate patterns that lead to the construction of inferences, predictions or hypotheses.

c) Defining operationally

It is creating a definition by describing what is done and observed. It is written in the language of students. Definitions are in context of students' experiences, not from the glossary, and not to be memorised.

d) Formulating hypothesis (Hypothesising)

This means tentatively accepting an explanation as a basis for further investigation. That is making shrewd guesses based on evidences that can be tested through experimentation.

e) Experimenting

It refers to designing one's own experiment to test a hypothesis using procedures to obtain reliable data.

The above-mentioned skills and integrated processes do not operate in isolation. Experimenting, for example, involves coordination among all the preceding basic skills and integrated processes.

Chapter VI

SUPPORT SYSTEMS AND RESOURCE MATERIALS

Support systems and resource materials are those facilities and materials that the teacher utilises for an effective curriculum transaction. Systematic and proper use of these provides the learner with a variety of experiences and helps to realise the educational objectives. The details of important support systems and resource materials in teaching physical science are given below.

1. Science Laboratory

The most important support system that assists the teaching and learning of science is science laboratory. Physical science teaching is different from teaching of other subjects because of the fact that most of the lessons are accompanied by demonstration and or laboratory work. Laboratory work supplements classroom activities. "Practical classroom experiments help in broadening pupils' experience and develop initiative, resourcefulness and co-operation" (Yadav, 1992). An effective and efficient teaching in science is possible only with the aid of a good laboratory with necessary equipments. Laboratory serves three main functions in students' learning. They are - - (1) deepening the students' understanding (2) developing skill in observation and (3) developing skill in measurement (Sharma & Sharma, 1971).

The place of laboratory in science learning is not mere illustration and verification of the taught theory; one learns to solve problems in the laboratory. Vanaja (2005) enumerates the major contributions of a science laboratory as follows.

1. A source of problems for students

A true science laboratory should be a source of innumerable problems. A sensitive science teacher can recognise them and draw the students' attention towards them. The teacher should be able to maintain an exploratory atmosphere encouraging investigations by students.

2. Provides for the solutions of problems that students encounter

In the laboratory, the students should get a chance for problem solving; to define problem, formulate hypotheses, gather and interpret data, test hypotheses, formulate generalisations and draw conclusions. The teacher should be able to create occasions for problem solving as part of laboratory work. S/he has to make the resources available for the students. The students must have the opportunity to design experiments, devise equipments and improvise apparatus.

3. Helps students to understand the scientists' role in society

Through laboratory work, the students understand the methods of investigation employed by scientists, the dependence of social development upon the scientific endeavour, and the implications of the findings of science on society.

4. Provides means for illustrations of phenomena and principles

Illustrations and verifications are important aspects in the study of science. Science laboratory provides the means for the illustrations of phenomena and principles, as well as for their application. In addition, it provides the means to verify facts, laws and generalisations.

5. Develops knowledge and understanding of the nature of science

Firsthand experiences obtained in the laboratory contribute to the building up of knowledge and understanding in students and facilitate abstractions.

6. Contributes to the development of skills, habits and attitudes

Through the activities in the laboratory the students develop attitudes and skills useful in daily life - - cleanliness, punctuality, co-operation, honesty, ability to use common instruments, etc.

The advantages of science laboratory in schools are:

1. Develops intuition and deepens the understanding of concepts
2. Enables the students to apply the concepts learnt in the class to new situations
3. Enables the students to experience basic phenomena
4. Develops critical, intuitive and rational thinking
5. Enables the students to learn to use scientific apparatus
6. Enables the students to learn to recognise and estimate errors
7. Develops reporting skills (written and oral)
8. Enables the students to practise collaborative problem solving
9. Enables the students to exercise curiosity and creativity by designing procedures to test hypotheses
10. Enables the students to test important laws and rules
11. Enables the students to appreciate the role of experimentation in science
12. Stimulates interest and excitement
13. Encourages the slow learners
14. Challenges the students, especially the gifted
15. Involves students in problem solving

Organisation of Science Laboratory

In the planning of science laboratory, there are several factors that need consideration. Only important factors are detailed here. First, the number of students working at a time should be estimated; second, the minimum space necessary for each pupil should be calculated; third, the different types of practical work (group and individual) that will be done in the laboratory should be known in advance. Also other space for storage and preparation should be accounted for.

The location, lay-out and furnishing of laboratory need special consideration. The location of the laboratory should be preferably at the ground floor. If possible, one end or extreme side of the school building should be selected for the purpose. A north-south orientation with a variation of 30^o on either side is recommended. Depending on the number of students working at a time, different plans have been suggested by several authors (e.g., Vaidya, 1971; Sharma & Sharma 1971; Gupta, 1985). The one suitable for the present needs and adaptable for future needs should be preferred.

In the furnishing of laboratory there are many items such as tables for demonstration, tables for experiment, electrical power supply, gas supply, water supply, sink, electrical light fittings, wall shelves, ledgers for balances, chalk board, etc., that need to be selected to meet peculiar demands.

Science Teacher and Laboratory Work

In order to make practical work most effective, the science teacher should always keep in view the following points:

1. There should be co-ordination of theoretical and practical work
2. The teacher should see that there is no mechanical repetition of the same experiment given in the textbooks. S/he should make additions and alterations in order to arouse reflective thinking
3. The experiments should meet the capacity of the particular students
4. The purpose of experiment should be made very clear to the pupils
5. The experimental details and observation notes should be made in the laboratory then and there
6. The teacher should sit at a place from where s/he can observe the work of each student

7. The notes written in the laboratory should be examined critically
8. General instruction should be given before the commencement of laboratory work. If assignment method is followed, then the teacher should correct the notebooks of the pupils a day before their turn for practical work. In case where the class is large and the equipment is inadequate, 'group plan' may be adopted. However, the merits and demerits of a group plan should be evaluated in making the decisions.

For a smooth conduct of the laboratory work, the teacher may prepare instruction cards. The card will include details such as:

1. Number of experiments
2. The purpose of experiments
3. The method to the adopted
4. Precaution to be observed
5. Method of tabulating the results
6. Conclusion

Records Kept in the Laboratory

For the smooth functioning of the science laboratory, the laboratory assistant or science teacher-in-charge will have to keep records of different items in the laboratory. The records related to laboratory are classified into four (Das, 1985). They are - - (1) permanent stock register, (2) stock register of chemicals, (3) stock register for breakable articles, and (4) order register. Each of these records is briefly described below:

(1) Permanent stock register

This register should list all articles, apparatus, equipment, specimen, etc., which are non-breakable or non-consumable and thus are permanent in nature. The list may be prepared in the alphabetic order with the details such as date of purchase, number or quantity, name of manufacturer, etc.

(2) Stock register of chemicals

This register should contain the name of chemicals listed in the alphabetic order. The current stock of each chemical should be indicated in appropriate units. This is the register for consumables and the register should be checked on a weekly or monthly basis to infer the current stock of the frequently used chemicals.

(3) Stock register for breakable articles

This register lists all articles made of glass, china, silica and such other breakable materials. The items should be listed in the alphabetic order with brand names so as to facilitate replacement and collection of dues from students.

(4) Order register

This register is the master register of everything contained in the laboratory. This register is the basic document that will provide information for the above-mentioned registers. The different columns in this register should indicate date of order, order details, name of the company, price, number or quantity purchased, date of delivery or receipt, date of payment, voucher details and remarks. It is desirable to have a section for recording articles received as donation/gift.

Common Accidents in Laboratory and their First Aid

Physical science laboratory work involves some elements of danger. The science teacher should foresee the possible dangers and caution the students about these dangers. In the laboratory, students may have to work with a.c. power supply, inflammable and explosive substances, strong acids and alkalies, metals like sodium, potassium and mercury, gases such as chlorine and bromine. Glasswares, chinawares and other equipments may cause cuts, burns and bruises. Therefore, it is essential that a teacher should know the first aid for the common accidents in the laboratory. The common accidents and their first aids are listed below.

1. Cuts: Stop bleeding by applying pressure on the wound in the form of a dressing. The wound should be cleaned with a 1:10

lotion of dettol and water or any antiseptic. Minor cuts should be treated with tincture of iodine on a pad of cotton wool. No washing is necessary unless the wound is dirty.

2. Dry burns: Prevent contact with air by applying vaseline or olive oil.

3. Acid burns: Wash immediately with large quantities of water and then with sodium bicarbonate solution.

4. Alkali burns: Wash with running water and then with 1% acetic acid or lemon juice.

5. Phosphorous burns: Wash with water and cover with cotton wool soaked in dilute silver nitrate solution.

6. Acid in eye: The eye should be opened and closed under running water. Then it should be washed with 1% solution of sodium bicarbonate.

7. Alkali in eye: The eye should be thoroughly washed with water and then with a solution of 1% boric acid.

8. Solid in eye: Turn the eye-lid gently over a match-stick, then use camel hair brush dipped in glycerine to remove the solid.

9. Poisoning: In case when solid or liquid poison is swallowed, the procedures to be adopted are given below.

   (a) Corrosive: White of egg or milk and rice or barley water should be given

   (i) Acid: If the poisoning is due to some acid, first allow to drink water and then lime-water or milk of magnesia [$Mg(OH)_2$]

   (ii) Alkali: If the poisoning is due to alkali, first allow to drink water and then acetic acid or lemon juice.

   (b) Non-corrosive: A table spoon of salt or mustard oil in a tumbler of water should be given to encourage vomiting. White of egg or rice water may also be given. If the nature of the poison is not known activated charcoal, magnesium oxide and tannic acid in the ratio 2:1:1 may be given. The mixture is known as the universal anti-dote.

(c) **Gas poisoning:** should be allowed to breathe fresh air and some stimulants such as hot tea or coffee may be given. To counteract chlorine or bromine, smell ammonia and rinse the mouth and throat with sodium bicarbonate solution.

10. Electric shocks: The electric switch should be immediately turned off. The person should be made to lie on his back and should be allowed to breathe fresh air. In case s/he can drink some liquid s/he should be given some tea or coffee. In case, the condition is serious, artificial respiration should be given.
11. Unconsciousness: The person should be brought to an open place to breathe fresh air. S/he should be made to sit in such a way that his/her head should be between his/her two knees. In addition to this, s/he should be given some stimulants such as tea or coffee to drink.
12. Fire: Wrap the person in fire-proof blanket. If an inflammable substance is on fire, close the mouth of the vessel. Small fire due to oil, phosphorus, etc., can be put out by smothering them with large quantities of dry sand. If the fire is due to gas or electricity, the source of supply or the main connection should be cut off.

First Aid Kit

In the science laboratory, following items should be kept in a box to facilitate first aid. The items are:

1. Acetic acid (1% to 5%)
2. Ammonium hydroxide (1% to 5%)
3. Burnol
4. Sodium bicarbonate (1%)
5. Silver nitrate
6. Boric acid
7. Tannic acid
8. Hydrogen peroxide (3%)
9. Glycerine

10. Ether
11. Castor oil
12. Mustard oil
13. Mineral oil
14. Liquid paraffin
15. Adhesive tape roll (½″ or 1" wide)
16. Bandage (various size)
17. Camel hair brush
18. Dropper
19. Dettol
20. Sterilized dressing
21. Common salt
22. Starch
23. Tincture of iodine
24. Universal anti-dote

The cupboard containing first aid materials must be left open and a list of accidents and their corresponding first aids should be hung near it.

2. Science Library

Science library is an essential support system for a good science teaching and effective learning. It provides supplementary information for the teacher and student. In a world of 'information', a science teacher has to proceed at par with the latest trends in education; both in subject matter and in pedagogic practices. Other wise s/he may fail in his/her task of instruction. A well-equipped library helps the science teacher to gather information about the advancements in science and its classroom implications. In addition, the twenty first century student is not a passive learner, but an active participant in the educative process. The Science library provides a number of resources, which are helpful in the learners' pursuit of knowledge construction.

Advantages of Science Library

The important advantages of a science library can be summarised as follows (Vanaja, 2005):

1. Source of knowledge

It helps both students and teachers to keep themselves up-to-date in various dimensions of scientific knowledge. It provides supplementary information to the topics prescribed in the syllabus.

2. Source of latest developments in science

This is an era of knowledge explosion. What is new today in science is old tomorrow. New science books are being written everyday for giving information about the new discoveries and inventions. The students and teachers can be acquainted with such fast developments through the books, journals and electronic resources provided in the libraries.

3. Source of information about new methods of instruction

With the widening of knowledge, more appropriate instructional strategies, methods and techniques are to be incorporated in the learning process. The materials in the library may help the teachers to be acquainted with the latest methods and techniques of instruction.

4. Helps in better learning by students

The students get a chance to read several books on the same topic written in various styles by different authors. It stimulates their thoughts and helps them to comprehend the concepts in a better way.

5. Inculcates good reading habits in students

The use of library develops interest in reading and acquiring knowledge. Gradually it helps them in developing good habits like reading with concentration, self-study, punctuality, discipline, caring for books, etc.

6. Provides inspiration

The reading materials narrating scientific inventions and discoveries as well as the life history may thrill the students and inspire them to undertake scientific endeavours.

7. Develops scientific attitude

The use of library helps the students in learning the scientific method of solving problems and in developing scientific attitude in their thoughts and actions.

8. Good use of leisure time

The library provides a means for fruitful use of leisure time for students as well as teachers.

9. Fosters creativity

The use of library may foster the creative talents of students in writing articles in journals, designing and executing science projects, developing scientific hobbies, etc.

10. Helps in developing values

The proper use of library helps to develop values such as co-operation, orderliness, punctuality, tolerance, etc.

I. Organisation of Science Library

The following points should be borne in mind while organising a school library.

a) Place and accommodation

Science library can be established as a separate library. If it is not possible due to economic or administrative reasons, it can be established as a part of the general library or can be attached as a separate facility near the classroom. Whatever may be the arrangement, the students should have an easy access to the books in the library.

b) Library-in-charge

If the science library is a part of the general library, the librarian could be in charge of the science section also. In such cases, it is nice to have a 'library-teacher' for each class who can guide students to select books relevant to their standard. If the science library is attached to science lab or classrooms, the science teacher should be the in charge of such arrangements. S/he can utilise the service of selected students in the various activities of the library.

c) Classifying science books and reading materials

In general, the books and materials to be kept in the science library may be categorised as follows:

(i) Prescribed books for each standard

(ii) Books providing detailed information in every branch of science

(iii) Books on latest developments and progress in science

(iv) Books on discoveries and inventions in science

(v) Books on the historical landmarks in the field of science

(vi) Books narrating the life history of scientists

(vii) Books on scientific hobbies and fiction

(viii) Interesting pictorial and well-illustrated books on science for creating interest in science reading

(ix) Science periodicals, journals and magazines

(x) Materials like charts, pictures, etc. to be used as an aid for the teaching and learning of the different topics in all branches of science

(xi) Reference books, dictionaries, encyclopaedias, etc. related to the facts and process of science

II. Management of Science Library

A collection of books and reading materials will not make the science library beneficial for students and teachers. The following points are to be remembered in the management of a science library.

a) Proper classification of books

The books should be properly classified and kept so that, the reader may easily locate a particular book on the given topic. Giving reference number to each book will make this task easy.

b) Proper service and maintenance

For the proper maintenance of a science library and effective service, the following things are to be considered:

(i) A lending register should be maintained. It should include the names of students, date of issue of the book, date of return of the book, etc. This will also help the teacher to understand the number of students interested in reading the science books.

(ii) Students should be instructed not to tear any picture or page from the books and magazine of the library. They should also be told and made to learn the proper way of using the books and materials without getting them damaged in any way.

(iii) The books and the materials should be protected from the white ants, cockroaches and other harmful insects by taking necessary precautions.

c) Rules for use

Rules of library should be properly displayed for the information of the readers. Major rules that have to be obeyed for a smooth functioning of a library are given below:

(i) Every class should have a fixed day and time for getting books issued to them and also for returning the same

(ii) Period for which the book is issued should be made clear to the students

(iii) The students should know clearly that they have to return the books within the stipulated period

(iv) There should be a specific period in the timetable known as library period for attending the library to read books and other reading materials

(v) The students should be made to observe silence and keep discipline in the library

III. Promoting Students' Interest in the Use of Science Library

The following ways and means may be adopted by the teachers or organisers to create interest in students in the library work:

(i) The teacher should give titiles and names of authors of references books during the classroom teaching or demonstration

(ii) If possible the teacher may bring good books from the library and show them in the class by emphasizing their salient features

(iii) The students may be asked to take necessary notes from the library books and read them out to the whole class for the benefit of others

(iv) Discussion and debates on the topics of scientific interest should be encouraged among the students using books and material available in the library

(v) The student should have full freedom in the choice of books for reading. They may be helped properly in selecting, locating and getting the books on the subjects of their interest

(vi) Information regarding new arrivals may be displayed on the bulletin board of the library

(vii) Science club activities, science fairs and exhibitions, science magazine of the school, wall magazines and organization of different houses for the co-curricular activities can do a lot in creating the necessity of consulting library and collecting necessary information from it for the successful running of such cocurricular activities. A wise teacher should make use of them for attracting students to read in the library

(viii) Enthusiasm and interest on the part of the students in establishing science library can be created by taking proper steps in this direction by the teacher. The initiative, zeal and enthusiasm of the science teacher is of great importance in creating students' interest in the use of library

3. Syllabus

Syllabus is the core of the curriculum that outlines the content to be taught in a class for a period of study. It is a specific, systematic and hierarchically ordered arrangement of the content learned during the course of study. Syllabus functions as a support system and guides the teacher, to organise and complete the instructional process in stipulated time. It is a sketch that helps to prepare textbooks, workbooks, teachers' handbooks, source books, lesson transcripts, learning materials, etc.

Syllabus provides a plan of the course outline (hours of instruction of each unit, details of examination, etc.), course objectives, modes of transaction as well as the learning activities related to the content.

Principles to be considered while framing a syllabus in science

Joseph (1982) enumerated the following principles for framing syllabus for high school science.

1. A syllabus framed should be useful in realising the aims and objectives of teaching science
2. It should be related to the natural interest and activities of children at various stages of their development
3. Topics must be selected as far as possible from pupils' environment.
4. The syllabus should be broad and comprehensive enough to provide pupils an understanding of science as a whole.
5. The high school science should be primarily a preparation for life and not for higher studies in science.
6. The content chosen should be in accordance with the learning capacity of the pupils.
7. Undue importance to specialisation on different branches of Physics and Chemistry should be avoided.

8. The syllabus should be flexible and should allow the teacher to make slight alterations. There should be provisions to include topics of local importance.
9. The syllabus should also take into account the time allotted for the subject in the timetable.
10. It should incorporate the correlation aspects in science.
11. The arrangements of the topics in the syllabus should be in accordance with the psychological principles of learning
12. It should include the materials which help in the appreciation of work and sacrifice of great scientists in their search for truth.

4. Textbook

In science teaching and learning the importance of textbook as a resource material cannot be underestimated. "The textbook is almost widely used of educational teaching instruments… Indeed, the text book is almost synonymous with schooling" (Thurber & Collette, 1964, p. 227). The textbook was once considered as a main source of information. The concept of textbook has changed considerably over the decades. However, today it is an indispensable part of study, as a beacon to the student in his/her learning activities.

A science textbook is usually divided into sections or units, which are built around specific topics. It contains an introductory section, which reviews the content of the book, attempts to define science, and alerts the reader of the relevance of the content, etc., thus attempting to set the stage for the year's programme.

Each section in the textbook starts with provision for some activity that prepares pupils for the work and to the body of each section. Each section presents printed information, supplemented by illustration and suggestion for supplementary activities such as experiments, demonstrations, readings, etc. All units end with questions for evaluation along with a list of expected learning outcomes and technical words used. Modern textbooks provide glossary of the technical terms at the end of the book. Biographical sketches of scientists and accounts of specific developments are given in an attention-capturing manner by bold faces, special fonts, boxes, etc., to supplement each unit. Good science textbooks close with name index and subject index to help students to refer the relevant pages.

Characteristics of a good text book

Thurber and Collette (1964) suggested six criteria in the selection of a good text book. They are:

1. Content
2. Organisation
3. Literary style and vocabulary
4. Illustration
5. Teaching aids
6. Mechanical make-up and appearance

Each of the above criteria is detailed below

1. Content

(a) The textbook should be appropriate for the age level and experience of the pupils

(b) The subject matter of the textbook should be consistent with the needs and interests of the pupils

(c) The content should reflect the unknowns and uncertainties in science as well as the known

(d) The content should cover the prescribed syllabus

(e) Factual materials given in the text book must be accurate

2. Organisation

There are different patterns of organisation that are common in science textbooks. The college textbooks follow the logical organisation in which the concepts and principles are developed in a way that an educated person might organise them. The logical organisation is often deductive in nature. The second type, psychological organisation, is followed in school level textbooks in which the material is presented from the pupil's viewpoint. The approach is mostly inductive in nature. The following points must be considered in the organisation of the textbook.

(a) The content should be organised from simple to complex

(b) The organisation should follow the inductive development of the content

(c) Whenever possible the subject matter should be presented as a problem that has no ready solution

(d) The organisation of the content should challenge the attention and hold the interest of the pupils

(e) The content organisation in units (chapters) should be of suitable size and arranged into a well-connected course

(f) The organisation should inform the student of the correlation of the different units

3. Literary Style and Vocabulary

The style of a textbook is important given the age level of the student for whom it is meant. The vocabulary should be adjusted to the capacity of pupils and technical terms should be used only when it is necessary. There are computer programmes that will evaluate the appropriateness of vocabulary used in a textbook for specified age level. The readability of a textbook is an important consideration in its evaluation. The style should be judged based on:

(a) Length of sentences

(b) Directness of sentences

(c) Number of ideas per sentence

(d) Use of lead sentences for a paragraph

(e) Continuity of thought

4. Illustration

The quantity and quality of illustrations needs consideration. Photographs should be clearly reproduced. Diagrams should be carefully prepared. Colour to the illustrations adds to their teaching value. Illustrations should be well-selected and should amplify the materials printed on the same page. The following points are worth considering:

(a) Illustration should be sufficient in number, size and quality

(b) There must be good variety of illustrations like charts, maps, diagrams, graphs, etc.

(c) The illustration must be well-distributed throughout the book

(d) The illustration must be suitably labelled

5. Teaching Aids

The teaching aids that are relevant to each unit should be incorporated along with the text material. This will help the learner cognitively in processing the information. There must be:

(a) Sufficient number of experiments described and suggested

(b) Adequate laboratory exercises should be detailed with directions

(c) Suggestions of projects and problems where the knowledge can be applied should be mentioned

(d) Suggestions for the organisation of reviews, summaries, and suggestions for further study including references should be provided

6. Mechanical Make-up and Appearance

Artistry of cover, durability of binding, size of the book, quality of paper, length of line and size and legibility of type (font size) are considered under this heading. The book should have an attractive overall appearance. The cover design and the colour of binding should be attractive. The two-column format with a wide margin will be more attractive. The white space between lines adds to the ease of reading. The following points may be considered under this heading:

(a) Paper quality – thickness, whiteness, finish, etc.

(b) Printing font size appropriate for the age level

(c) Spacing between lines and words

(d) Attractive cover

(e) Strong and durable binding

(f) Reasonable cost

The above six criteria can be used to evaluate textbooks. Various scorecards and checklists have been devised to make the selection of textbook as objective as possible. For example, Hunter developed a scorecard for textbook evaluation with seven major factors. The seven items and distribution of scores are given below (cited in Thurber & Collette, 1964).

1.	Educational rank of author	50
2.	Mechanical make-up and cost	100
3.	Psychological soundness	300
4.	Subject matter	250
5.	Literary style	110
6.	Learning exercises	140
7.	Teachers' help	50
	Total	1000

Vogel suggested a spot check evaluation scale that may be a good guide for selecting a science textbook. The major criteria are grouped under ten major headings (cited in Thurber & Collette, 1964). They are - - (1) qualification of the author, (2) organisation, (3) content, (4) presentation, (5) accuracy, (6) readability, (7) adaptability, (8) teaching aids, (9) illustrations, and (10) appearance.

Vogel's card is suggestive and at the same time seems subjective. All the above ten criteria suggested by Vogel have sub-items, the first two heads have four each and the rest eight heads have five each. Each sub-item is considered while scoring. Each sub-item has a value of two points and the score obtained for each head is termed as partial score. The value of each item under each head is totalled against the part of score. The partial scores of each head were then counted and the overall value is scored.

Uses of science textbook

1. Science textbook provides authoritative information for the pupils to supplement classroom instruction and laboratory work
2. It is a source of factual materials in the preparation of assignments both for teachers and for students
3. It provides the necessary illustrations that help in easy comprehension of ideas
4. It supplies follow-up exercises, numerical problems and other learning devices, which would serve as a means of applying the knowledge gained
5. It helps pupils in systematic revision
6. It provides description of processes particularly those outside the experience of pupils
7. It provides a background for thinking and further study
8. It supplements students with biographical and historical sketches to realise the cultural value of science.

5. Resource Unit

"The term resource unit in science refers to a huge collection of science materials and activities related to a particular topic" (Joseph, 1982). It is a resource of materials from which a teacher can select suitable topics, activities, books and audio-visual aids for curriculum transaction. The resource unit is much more comprehensive than a teaching unit. It differs from the teaching unit in purpose, scope, making and organisation. It is a broad reservoir of information, activities and materials from which a teaching unit may be built. It is a guide and a store house for an enthusiastic teacher, to deal with his subject matter more effectively. A science teacher should be wise enough to make purposeful use of contents and suggested student activities; s/he is not expected to deal everything given in the resource unit.

A team of experts usually prepare the resource unit during workshops, in-service programmes, etc. The steps involved in the preparation of a resource unit are:

1. **Title:** Describes the content in simple, attractive and self explanatory manner
2. **Introduction:** Provides the social and scientific significance of the unit and also indicates why it becomes important to children of this particular age level
3. **General objectives:** Brief statements specifying the expected learning outcomes
4. **Content analysis:** Analyses the content exhaustively and presents it in simple and clear language
5. **Activities of the unit:** Provides explicit descriptions of the projects, demonstrations, experiments and field trips, which can be used/undertaken for the complete treatment of the unit
6. **Teaching materials and sources:** These materials are divided into those suitable for teachers' use and those for students' use. The reference materials for the teachers include a careful selection of books, pamphlets, periodicals, articles, films, charts, etc. The reference materials for students include textbooks, supplementary reading materials, periodicals, etc. Audio-visual aids, which help in effective presentation of the lesson, may also be described here.
7. **Evaluation procedures:** As the final step, evaluation procedures appropriate for the unit have to be mentioned. Measuring instruments, sample tests, informal evaluation techniques, methods of evaluating students' works such as projects, seminars, assignments, practical, etc. are included in it.

6. Workbook

A workbook is a supplement to the science textbook. There are several functions for a workbook in the learning process. Workbooks are usually organised in the same order that the textbooks follow. It provides for different types of activities. These activities include - - forms (proforma) for reporting data, diagrams to be labelled, blank spaces for drawing diagrams, suggestions for supplementary work, study guides for preparing assignments and self-testing devices. The self-testing items included in the workbook are: multiple-choice items, fill in the blank items, matching type items, short note question and problems of various kind.

Workbook minimises the work-load of teachers in preparing worksheets, assignments and laboratory experiments. Also, the test items help in the task of evaluation. Since the workbook is prepared by a group of teachers, the test items will be of better quality.

Advantages of workbook

1. It promotes self-learning and self-assessment
2. It gives practise in what pupils have learnt in the class and thereby reinforces learning
3. It promotes scientific thinking
4. It makes learning more structured
5. It provides for systematic practice of skills
6. It helps in revision of topics included in the textbooks

Limitations of workbook

1. It is highly organised and not flexible
2. It demands uniform outcomes from the students
3. Independent work is discouraged

7. Teachers' Handbook

"It is a ready reference material for the teacher to supplement his classroom teaching" (Joseph, 1982). It contains summaries of chapters in the textbook, conceptual development of topics, statement of objectives to be realised, explanation of significant terms, facts, concepts, principles, etc., learning experiences to be provided, precautions to be taken while demonstrations, activities appropriate to each topic, evaluation tools, assignments for pupils and suggested reading materials for the teacher and pupils.

Advantages teachers' handbook

1. It equips the teacher with sufficient knowledge about what is to be taught
2. The problem of finding out suitable learning experiences and activities for teaching different lessons is easily solved
3. It helps the teacher to adopt appropriate methods to teach every topic
4. It helps the teacher in the planning and execution of different tasks involved in teaching
5. It makes the work of the teacher easier

8. Reference Books

Reference books are used to supplement knowledge gained in the classroom and to acquire new knowledge (Das, 1985). Reference books provide a means for self-improvement. These include dictionaries, yearbooks, government reports, journals, encyclopaedia of science, etc. They are authentic and reliable sources of information. Authors of the reference books will be persons who have made original contributions in the field.

The students must be given special training in the use of reference books. The teacher should ensure that the suggested reference materials are easily comprehensible, readily available and appropriate for the age levels of the pupils. The teacher should be familiar with these materials in advance to suggest them to his/her students.

Advantages of reference books

a. It supplements the classroom learning
b. It facilitates pupils' self-study habits and spirit of self-effort
c. It helps the pupils to workout assignments
d. It stimulates scientific thinking and inculcates elements of scientific attitude
e. It leads students to new vistas of knowledge

9. Supplementary Readers

Supplementary readers will introduce students to new materials and meet their varied needs and interests (Washton, 1961). They refer to literature other than the prescribed textbooks or reference books but furnish additional details on science topics. These include books on different aspects of science, newspaper supplements, magazine articles, brochures, etc. The interested learners can utilise a number of supplementary books to deepen their subject competencies.

Good supplementary reading in science will serve to stimulate additional reading in the same or related topic. This can develop initiative and self-direction in the learners. Teachers should encourage their students in reading supplementary materials, by helping in proper selection of materials that are challenging to the learners.

Advantages of supplementary readers

a. It helps to develop the intellectual potentialities, deepens scientific interests, and cultivates the traits of scientific attitude

b. It supplements and integrates classroom learning

c. It inculcates self-study habits and promotes independent reading

d. It strengthens linguistic ability and develops literary tastes

10. Audio-visual Aids

'Audio-visual Aids', 'Audio-visual Media', 'Instructional or Educational Media', 'Learning Resources', 'Educational Communication Technology', and 'Information Communication Technology (ICT) in Education', all these refer to the same thing. Earlier the term used was audio-visual aids in education. With the advancement in the means of communication and technology, educators coined new terms.

Sensory experience forms the foundation for intellectual activity. Sensory aids effect an economy of time in learning. For long, the common practice to communicate knowledge has been by means of written or oral language. But language has many limitations which may contribute to learning difficulty. Generally, modern educators recognise in audio-visual materials such basic values as concreteness, enrichment, and dynamic interest. The number of aids for teaching has become so numerous that today a teacher of any subject need not resort to any of the archaic methods of teaching. Even the most abstract concept can now be presented to the pupils in a concrete way by means of more than one aid (Sampath, Panneerselvam, & Santhanam, 1998).

Definitions of Audio-visual Aids

Audio-visual aids are those sensory objects or images, which initiate or stimulate and reinforce learning.

Audio-visual or teaching aids are instructional materials or devices that help a teacher in the effective realisation of his/her objectives by calling upon the auditory and visual sense of his students (Mangal, 1995).

Audio-visual aides are those aids which help in completing the triangular process of learning i.e., motivation, classification and stimulation (Good, 1945).

Audio-visual aids are those devices by the use of which communication of ideas between persons and groups in various teaching and training situations is helped. These are also termed as multi-sensory materials (Dale, 1967).

Significance of Audio-visual Aids in Education

Audio-visual aids have great significance in the modern educational scenario. It helps both teachers and students in realising the teaching-learning objectives. Some of the general advantages of using audio-visual aids are:

1. **Effective substitute for direct contact of students with the environment – physical and social (Vicarious experience):** live or recorded telecast of events through television or radio, motion pictures, carefully prepared slides, etc., can help the teacher surpass the limits of time and space and provide students needed experiences of abstract concepts/ideas; of distant places/people; of complicated/dangerous process, etc.

2. **Guarantee maximum use of senses:** involvement of more sense organs leads to rich and better teaching-learning experience.
3. **Better motivation:** builds more interest and attention energising learners to learn effectively out of their inner urges, instincts, drives and motives.
4. **Reality:** brings a bit of real life into the learning situation and helps students gain the concept they are learning much faster than through reading of book.
5. **Development of higher faculties:** verbalism promotes memorisation. Use of audio-visual aids triggers the imagination, thinking process and reasoning power of the students and call for creativity, initiative and other higher mental activities.
6. **Positive transfer of learning and training:** use of audio-visual aids help in the learning of other concepts, principles and solve the real problems of life in future.
7. **Meets individual differences:** learners vary much in their learning styles, some are auditory (prefers things to be heard), some are visual (prefers things to be seen), while some others are multi-sensory (learn better by doing). The use of variety of audio-visual aids helps in meeting the needs of different types of students.
8. **Provide reinforcement:** increases the probability of re-occurrence of the responses and render help in the process of teaching and learning.
9. **Based on maxims of teaching:** helps the teacher to follow the maxims of teaching such as concrete to abstract.
10. **Concept formation:** thinking and reasoning are the core of concept formation. Audio-visual aids minimises verbalism and evokes thinking and reasoning. Proper use of elicitation can lead to better comprehension and concept formation.
11. **Continuity of thoughts:** helps in ensuring continuity of thought and which is the basic necessity for real education.

12. **Ensures better retention:** increases retention as they stimulate the learner to the situation in which learning takes place.

Classification of Audio-visual Aids

Two basic approaches to classification of audio-visual aids are discussed below:

1. **Traditional Approach:** in this style the audio-visual aids, materials and equipments are classified under four heads as mentioned below:

a) **Audio aids:** those aids that call upon the auditory sense and thus help individuals to learn through listening come under this head. Radio broadcasts, audio-cassette recordings, audio CDs, etc. are examples for this category.

b) **Visual aids:** those aids which call upon the visual senses and thus help individual to learn through viewing come under this head. These aids may be further sub divided as: (i) Projective and (ii) Non-projective aids.

i. **Projective aids:** include visual aids such as silent motion picture, film-strips, slides, transparencies, epidiascope, magic lantern, micro-projections, opaque projector, overhead projector, etc.

ii. **Non-projective aids:** include aids that are appealing to sight - **graphic aids** such as photographs, posters, maps, charts, graphs, flash cards, cartoons, comics, etc., **display materials** such as chalk board, flannel board, bulletin board, magnetic board, peg board, material for school museum, etc., **three dimensional aids** such as globe, models, objects, specimens, mock ups, dioramas, puppets, etc.

c) **Audio-visual aids:** those aids that call upon the auditory and visual senses and thus help individuals to learn through listening as well as viewing come under this head. Television, sound motion-picture, synchronised audio-slide projection, radio vision, computer assisted instruction, etc. are examples for this category.

d) **Activity aids:** those aids that call upon the five senses and help individuals to learn thorough listening, viewing as well as doing come under this head. Dramatisation, role playing, laboratory experiments, field trips, study tours, group discussions, debates, etc. are examples for this category.

2. **Technological Approach:** in this style the audio-visual aids, materials and equipments are classified under three heads as mentioned below:

a) **Simple hardware:** magic lantern, epidiascope, slide projector, filmstrip projector, opaque projector, overhead projector etc. come under this category.

b) **Hardware:** radio, television, record player, tape recorder, video cassette recorder, CD/DVD players, 16 mm projector, teaching machines, computers, liquid crystal display monitors, LCD projectors, etc. come under this category.

c) **Software:** slides, OHP transparencies, filmstrips, pictures, photographs, printed materials, graphic aids such as graphs, charts, maps, diagrams, cartoons, posters, etc. and three dimensional objects like models, dioramas, specimen, etc. come under this head.

Essential Audio-visual Aids

The audio-visual aids that are most important in the classroom context are discussed below:

1). Chalk board or Black board

Chalk board or black board is a reusable writing surface on which text or drawings are made with chalk or other erasable markers. Black boards were originally made of smooth, thin sheets of black or dark grey slate stone. Modern versions are often green or brown and are thus sometimes called a green board or brown board instead.

It is the oldest and the best friend of teachers and the unique device which still stands tall in the midst of newer, better and sophisticated gadgets. It is the cheapest, but valuable and most universally used teaching aid. It is considered '*sine qua non*' (main thing) of our educational system, because it helps in almost all activities of the teacher like planning, illustrating, point clinching, summarising, reviewing, etc. In short it is the most convenient surface where the teacher can develop subject matter visually. It helps the teacher make way for oral-visual switching and thus maintain attention of the students.

Uses of black board

1. Helps to seek attention of the class by illustrating the salient features of the lesson.
2. Facilitates in developing interest among pupils by way of writings and drawings.
3. Provides space for decorative and creative works.
4. Helps the teacher to focus students' attention on the topic of discussion.
5. Helps to review the day's work in a short span of time.

Types of chalk board

1. **Paint coated pressed wood:** Hard board or any plywood surface coated with special dull paint for black board.
2. **Dull finished plastic surface:** PVC or laminated plastic sheets can be used but these boards are not durable and cost effective.
3. **Porcelain coated steel surface:** The highest grade chalkboards are made of rougher version porcelain enamelled steel (black, green, blue or sometimes other colours). Porcelain is very hard wearing and chalkboards made of porcelain usually last 10-20 years in intensive use. This can also serve as **magnetic board.**
4. **Ground glass board:** the writing surface is ground glass and there is no coating of any material on the writing surface to wear out. It can be made in a variety of colours. Only one side of the glass plate is ground. The back surface is painted with good quality paint of the required colour or suitable coloured material like cloth could be used in the back ground.

Suggestions for using black board

a. Hold the chalk between the thumb and the fingers with the non-working end of the chalk pointing to the palm of the hand.

b. Do not over crowd materials; write only important points

c. Ensure optimum size of letters and legibility of words

d. Give adequate spacing between letters, between words and between lines

e. Avoid slanting of letters

f. Use coloured chalks especially while drawing diagrams

g. Ensure proper lighting conditions to avoid chalk board glare

2). Charts

The word 'chart' is derived from the Greek word '*Charta*' which means 'a prior thought sketch of action.' Charts are used for easy understanding of large quantities of data and the relationship between different parts of the data. Usually charts are combination of pictorial, graphical or numerical material which presents a clear visual summary. Charts can usually be read more quickly than the raw data that they come from. They are used in a wide variety of fields, and can be created by hand (often on chart paper or graph paper) or by computer, using a charting application.

Uses of charts

1. Showing relationship by means of facts, figures and statistics.
2. Presenting materials symbolically
3. Showing continuity of a process
4. Presentation of abstract ideas in visual form
5. Showing development of structure
6. Creating problem to pave way for thinking

Types of charts

1. **Narrative chart:** is an extended left to right arrangement of

facts or ideas for expressing events in a process, development of an issue, progress during a course of time, etc.

2. **Tabulation chart:** is an expression of facts and ideas arranged in left to right or top to bottom manner. This type of charts helps to compare numerical data and list out ideas.

3. **Flow chart:** is used to sequence and show functional relationship in happenings of any social as well as physical phenomena. It also shows organizational set up and basic tenets of administrative utility.

4. **Pictorial chart:** is prepared by mounting or pasting a picture on a chart paper. It is a systematic arrangement of key facts and ideas in graphic or pictorial form. Such charts help in eliciting information and are useful for low age group students.

5. **Chain chart:** is a circular or semicircular arrangement of facts and ideas for expressing a cyclic process or a process of transition.

6. **Tree chart:** is a symbolic presentation through roots, trunk, branches and leaves of a tree. It gives an effective way of showing the development or growth of a thing.

3). Models

A model is a true representation of a real thing which is either very big like earth or very small like an atom. They are scaled replica of three dimensional things or representation of real things. Models are concrete objects with manageable dimensions; they simplify the reality and demonstrate processes. Models offer a kind of shortcut or substitute for the real things and sometimes models can be more effective than reality. Being three dimensional, models evoke creativity, better interest and simplify matters.

Uses of models

1. Models make abstract ideas concrete
2. Provide convenience to reduce and enlarge objects to observable and manageable size
3. Easy demonstrations as they provide interior view of objects and machines

4. Pave way for building creativity in students
5. Give a firsthand experience on distant, unattainable and dangerous things or processes

Types of models

Models are classified into four. They are:

I. Classification based on size

1. Enlarged scale model, for example, model of an atom
2. Reduced scale model, for example, model of a volcano

II. Classification based on make style

1. Three-dimensional model, for example, model of an aircraft
2. Sectional model, for example, model of a transformer
3. X-ray model, for example, model of a bio-gas plant

III. Classification based on function

1. Static model, for example, model of a dam
2. Working model, for example, model of a water pump

IV. Classification based on the way of presentation

1. Isolated Entity, for example, model of an electromagnet used in an electric bell
2. Integrated unit in a miniature set up, for example, model of planetary system

4). Over Head Projector (OHP)

The overhead projector is a comparatively new but a very useful development for classrooms and lecture theatres. The teacher instead of writing on the black board writes (facing the students) on a roll of cellophane paper called transparency. This transparency is placed on projecting glass and projected on the screen at the back of the teacher. For effective presentations previously prepared OHP transparencies can also be used. The name over head projector came from this fact that the projected image is behind and over the head of the speaker. The over head projector has similar optical elements as in film projectors and slide projectors, but has its own uniqueness.

Preparation of transparencies

Over Head Projector Transparency (OHPT) can be prepared by writing or drawing sketches over the transparent plastic sheets or rolls. Transparencies can also be prepared photographic technique or by getting Xerox copies of the materials on cellophane materials. Overlay techniques (placing one transparency over the other for projection) can enhance the effectiveness of presentations that require establishment of figure ground relationships. By selecting suitable colours for preparation of the transparencies the teacher can bring in realistic effects.

Advantages of Over Head Projector

1. **Large image:** a very large projected image in a minimum projection distance is offered
2. **Face the class:** the image formed in over the head and behind the speaker, so the speaker can face the audience and observe their reactions, the speaker can adjust the presentation to meet the response of the audience.
3. **Lighted room:** the equipment can be used in a well-lighted room which enables the presenter freedom of presentation even in lighted settings.
4. **Light weight:** the comparatively light weight and manageable size of the equipment makes it portable.
5. **Flexibility and versatility:** the visualization used can be prepared in advance or even during the time of presentation, this helps the presenter gain total control of presentation and generates interest in the topic presented.
6. **Homemade materials:** visuals can be made in minimum time and at low cost. The transparencies once made can be preserved and can be utilised again for subsequent lectures.
7. **Personalised presentation:** The projections can be coloured by use of coloured ink, it can be made impressive by step by step

presentations with appropriate use of overlays. LCD panel can also be fitted to the projection surface.

8. **Substitutes black board:** the presenter can write on the transparencies whenever he needs and can wipe it off afterwards with a clean cloth. It is also possible to use triacetate film roll that can be constantly rolled over the illuminated stage, so text written continuously could be presented on the screen.
9. **Comfortable stand:** the presenter has not to run from the machine to the screen to explain things to the audience. He can use a pointer or pencil to point out important details on a slide.
10. **User friendly:** The operation of the projector is quite easy. It simply demands turning the power switch on and off, and placing the transparency.

5). Film Strip Cum Slide Projector

Film strip cum slide projector helps to project photographic slides and film strips on to a screen or any white coloured surface like walls. These projectors are equipped with strong light source to supply an intense and focused beam of light on to the slide holder/film strip carrier. Slide holders are frames containing two slits into which slides are put manually or automatically one after the other for projection and film strip carriers consist of two rollers with toothed wheels to clamp the edges of the film strip.

Slides and film strips are used as teaching aids for supplementing the science teaching. It is possible with these aids to demonstrate something which is in normal course difficult to see through naked eyes and also helps to illustrate an application immediately after a principle has been developed. Photographs of relevant matter meant for projection can be developed in laboratories on celluloid slides or film strips and can be easily displayed.

Preparation of slides

Any picture or diagram, which will take more than five minutes to draw on chalkboard during the class period, can be reproduced on a glass slide and an enlarged image of the picture can be projected on a screen with a slide projector or epidiascope. The size of a standard lantern slide is $3^1/_4$" square or $3^1/_4$" x 4". At present 2" square slide is gradually replacing the $3^1/_4$" slide. The thickness of the standard $3^1/_4$" square slide is about $^1/_8$" being made up of two glass plates held together by a binding strip. Each glass plate is of $^1/_{16}$" thick.

The slide on which the picture is reproduced is protected by a similar piece of glass, and it is termed as cover glass. The slide and the cover glass are bound together at the edges by a piece of paper called binding strip. The binding strip is usually $^1/_2$" wide and is usually made of opaque paper. Readymade strips, one side glued are available, cello tape can also be used. Opaque paper or metal foils can also be placed between the two glass plates in order to make the required area transparent and the rest opaque.

The size of the picture should be restricted within $2^1/_4$"square so that the margin of $^1/_2$" is left all around. A white paper circle or similar marking is made at one corner of the slide as an indicator to help proper placement of the slide in the slide holder during projection.

There are several methods for slide preparation. Some of them are mentioned below:

1. Pictures are drawn on perfectly cleaned and dried glass plates with Indian ink using crow-quill pen or a marker pen.
2. An even coating of egg albumin (white of egg) or gelatin (1g gelatin in 25ml of water) is made on the glass plate with brush and dried. Pictures can easily be drawn with Indian ink and the slides can be coloured with any transparent water colour with fine brush. The density must be increased in stages and it must be remembered that once a particular density is built up, it cannot be reduced.
3. Diagrams can be drawn on cellophane papers (OHP transparency) with Indian ink or marker pens. The paper can be properly cut and placed in between two glass plates and bound.
4. Free-hand drawing using some sharp pointed tool can be made on a glass plate coated with opaque-paint/lamp-black/Indian-ink. The diagram will stand illuminated in a dark background

when projected, so these slides can also be called reverse slides

5. Objects, pictures, diagrams, etc. can be photographed or reproduced on reflex printing paper and with the help of negative; a positive print can be made on a photographic lantern slide or diapositive film using photo enlarger. The picture thus obtained can be suitably framed with the rigid cardboard mount with cut over picture area.

6). Projectors

Currently, there are three basic types of video projector technology in use. They are - - Cathode Ray Tube (CRT), Liquid Crystal Display (LCD) and Digital Light Processing (DLP); these refer to the internal mechanisms that the projector uses to compose the image.

Although the CRT video projector option is no longer available for general consumer use, it is still used in some commercial and industrial settings, and many older units are still in operation.

LCD was reserved for less expensive designs while DLP models has the performance edge for high-end projectors. However, recent advances have seen both technologies converge and in most cases there is less of a reason to pick one technology over another. LCD technology has improved immensely in the last decade while DLP models are more competitively priced than ever before. So in short, both technologies are now able to offer clear and lively images, the main consideration to make choice depends on the specific requirements such as brightness, resolution, contrast and connectivity.

a) CRT Projector

Cathode Ray Tube (CRT) projector is the largest and most widely used projector. When video projectors first arrived on the scene, television technology was based on the CRT, on which the viewer sees the television image. Three small CRTs, sometimes called "guns" (one for each primary colour), coupled with a light magnifying lens, can project a colour image onto a large screen in a darkened room. With the proper video processing circuitry, CRT size, and lens combination, a CRT projector can produce excellent high resolution images.

b) LCD Projectors

Liquid Crystal Display (LCD) technology is used by many electronic device manufacturers such as Epson, Hitachi, Sanyo and Sony. LCD projectors contain three separate LCD glass panels, one for red, green, and blue components of the image signal being transferred to the projector. As the light passes through the LCD panels, individual pixels can be opened to allow light to pass or closed to block the light. This activity modulates the light and produces the image that is projected onto the screen.

LCD is generally more 'light efficient' than DLP (ie. the same wattage lamp in both an LCD and DLP would produce a brighter image through the LCD). LCD projectors help to get beautiful coloured and a clear image even in a bright room and tend to produce a sharper image.

c) DLP Projectors

Digital Light Processing (DLP) technology can be found in projectors from manufacturers such as BenQ, InFocus and Optoma. DLP is the world's only all-digital display solution. DLP technology uses an optical semiconductor, known as the Digital Micromirror Device (DMD) chip to recreate source material. DLP gives higher contrast for images. They are generally more portable as fewer components are required. It has been claimed that DLP projectors last longer than LCD projectors.

7). Micro Soft Power Point

Microsoft Office Power Point is one of the most powerful presentation-software developed by the Microsoft Corporation. It is a software that is used to create and display information in the form of a slide show. It is also possible to incorporate graphics, sounds, animations and even videos to make it more interactive, interesting, attention capturing for the viewer. This helps to leave a permanent mark in the mind of the viewer.

Creating a new presentation

1. To launch the power point application, click on **Start** button

and move your pointer to **All Programs** find **Microsoft Office** and then click on **Microsoft Office Power Point**.

2. When the application opens click on Blank Presentation and then click on **OK**.
3. The Slide Auto layout option will open. Ideally your first slide should be the heading of your presentation, so choose the top left lay out by clicking on it. Then click OK. In the slide that opens out, click inside the box named 'Click to add title' and write the heading. Then click inside the box below named, 'Click to add subtitle' and write the sub heading (it could be your name).
4. Now add a new slide. To do so click on the Insert Menu Bar and click on New Slide. Choose the layout most suited to your needs and click OK. Click inside the box and begin typing the information. In this way create the presentation.

Creating a presentation based on suggested content and design

You can create a new presentation in several ways. You can start by working with the Auto Content Wizard, in which you begin with a presentation that contains suggested content and design. You can also start with an existing presentation and change it to suit your needs. Another way to start a presentation is by selecting a design template that determines the presentations design but doesn't include content. You can also begin with an outline you import from another application or with a blank presentation that has neither suggested content nor design.

Saving a new or existing presentation

Click File menu, and then click Save. Find the folder you want to save in, give a name for the file and click Save.

Saving a presentation to always open as a slide show

1. Open the presentation you want to save as slide show.
2. On the **File** menu, click **Save As**.
3. In the **Save as type** list, click **Power Point Show**.

Use of micro soft power point presentations in schools

Computer generated slide presentations can enhance the effectiveness of classroom lectures. Teachers can use it to emphasize main points and key announcements. The subject matter taught becomes more organised. From a student's perspective, class material is far more legible and interesting than notes written on the blackboard.

Advantages of power point

1. Support lectures by highlighting key points
2. Present tips and outlines
3. Present examples
4. Provide pictures and other graphics supporting the material
5. Stimulate interest by use of clipart and cartoons
6. Display assignment information
7. Make important announcements
8. Deliver key points at a parent-teacher meeting

Tips for using power point:

1. Avoid overcrowding and overloading of matter in slides
2. Make letter size readable without strain to eyes
3. Font selected should be bold and thick
4. Use capitals with purpose
5. Consider one central idea per slide
6. Insert duplicate slide rather than going back to the previous slide
7. Ensure maximum contrast between foreground and background
8. Use animation only with specific purpose
9. Attempt slide transition only with purpose.

11. CD-ROM

Compact Disc-Read Only Memory (CD-ROM) is a secondary storage device on which data are recorded and read by laser beams. It is also called laser optical disc. Read only means that nothing can be erased once written on the disc. Multiple writing is possible on the same disc if prompted during writing. It is used to hold pre-recorded text, graphics, and sound. Users have access only to the data imprinted on the disc by manufacturers.

The size of a Compact Disc is commonly 4.75" in diameter. Its storage capacity is 700 MB/80Min. A CD-ROM stores data on the surface of a poly carbonate disc, which is covered by a thin layer of reflective aluminium film (which gives it the silver look) and a layer of lacquer for protection. Data are recorded on CDs as binary information and is encoded by the lengths of pits and space between them. The data stored in the disc can be retained without loss or damage for a long time.

Advantages of CD-ROM

1. High storage capacity around 700 MB; helps to store large quantity of data in forms such as text, images and audio-video recordings
2. Economical; the production cost of a CD ROM is very low
3. Durability; can be preserved for a long time without damage
4. Easy to handle; the size of the disc suits for easy carriage, and it is easy to play the disc

12. Encarta

Encarta is a digital multimedia encyclopaedia published by Microsoft Corporation. The first edition was published in 1993. The current Microsoft Encarta can be considered the successor of the Funk and Wagnalls, Crollier, and New Merit Scholar encyclopaedias. None of these formerly successful encyclopaedias are in print now, being unable to adapt to the new market dynamics of electronic encyclopaedias.

The complete English version, Encarta Premium consists of more than 68,000 articles, numerous images and movies, and homework tools, and is available on the World Wide Web by yearly subscription or by purchase on DVD-ROM or multiple CD-ROMs. Many articles can also be viewed online free of charge, a service supported by advertisements. Its articles are integrated with multimedia content and may have a collection of links to websites selected by its editors. A sidebar may display alternative views or original materials relevant to the topic. Encarta's Visual Browser, available since the 2004 version, presents a user with a list of related topics. Its multimedia includes virtual 3-dimensional tours of ancient structures, 2-dimensional panoramic images of world wonders or cities; and a virtual flight program which moves the user over landscape. Encarta also includes a trivia game called "MindMaze" in which the player explores a castle by answering questions whose answers could be found in the encyclopaedia's articles.

13. Improvised Apparatus

The apparatus devised and made by a teacher or by pupils in the school laboratory or workshop is called improvised apparatus or homemade apparatus. It is not always possible to purchase apparatus especially the costly ones from the market. Or in certain other cases, suitable apparatus needed for classrooms may not be readily available. In such situations a science teacher has to fabricate some equipment for classroom and laboratory use. A teacher with imagination and skill will be able to make several useful appliances using locally available ordinary or scrap materials.

Improvisation in a country like India has great importance, as it is difficult to afford all equipments necessary for classroom teaching. In addition, making of improvised apparatus has a great role in developing scientific interest and attitude among the school children.

Many simple devices can be made from tin cans, cigar boxes, packing cases, electric bulbs, scrap metals, screws, nails, wire, cork, etc. These improvised apparatus have the special advantage of the whole of the apparatus being open to observation in contrast to the finished product available in the market.

Advantages of improvised aids

1. It is economical.
2. When the students make things with their own hand, they thoroughly understand the underlying principles. Hence, the homemade apparatus has high educational value.
3. It develops constructive and creative instincts in pupils.
4. It can inspire young children to explore, discover and invent new things.
5. It is based on psychological principle of learning by doing.
6. It provides opportunities for the use of initiative and resourcefulness.
7. Students learn to think critically and improve their work by auto-suggestions.
8. It helps to develop scientific attitude.
9. It has recreational values and helps to lay the foundation of useful hobbies.
10. It aids in securing motivation and creating interest.
11. It enables children to appreciate the difficulties of early scientists.
12. It enables the teacher to introduce variety into the nature of experiments.

14. Video Lessons

Video-tapes or video-cassettes are made up of materials that can store data magnetically. Video tapes emerged as storage devices that can store both auditory and visual signals. In the field of education they helped to store instructional materials for easy and repetitive use. These video taped materials can be played back through monitors in classrooms or audio-visual rooms.

Video-tapes can provide virtually instantaneous reproduction and in this sense it is superior to films. Video-tapes in the form of video-cassettes have made it more user-friendly and portable. The user can easily take the cassette and play it by inserting into the video player attached to the television. The potential advantage of video cassettes lie in the fact that control of the equipment and the learning process is placed in the hands of the learner through control over the mechanics of the machine. It helps the learner acquire a wide range of motor, intellectual, cognitive and interpersonal skills as well as affective aspects.

This type of instruction thus is advantageous in carrying out both individualised and group instructions. This instructional mode could be of great use in distance education, continuing education, adult education and literacy mission programmes. An example for a video lesson in science is "World of Chemistry" developed by MIT Massachusetts, USA.

The various audio-visual aids described above have the potential to make the teaching-learning more effective. However, no single audio-visual aid is superior to any other audio-visual aid. The teacher will have to select one audio-visual aid, given the nature of the content, age-group of the learner, the time available and the facilities available in a particular school. Knowledge of these aids should better equip the teacher to make a judicious choice in the curriculum transaction.

For example, an equation such as $F = ma$ can be written on a black board which may take only a few seconds. It will be a meaningless exercise to put the equation on a slide since enlarging the size of the letters will not serve any pedagogical purpose. Whereas, the cross-section of a dry-cell can be put on a slide or OHP because drawing the diagram on black board will take five to ten minutes which will not be time-effective. However, a simulation of the structure of atom should be prepared as a Power Point presentation because the other audio-visual aids are incapable of providing such learning experience. To sum-up, the ingenuity of a teacher depends on his/her optimum use and choice of the various audio-visual aids available.

Chapter VII

LEARNING: A GENERATIVE PROCESS

Science education researchers have shown considerable interest in Ausubel's and Gagne's learning theories which give importance to the role played by the prior knowledge in learning. However, they were considering the theory of learning hierarchy and theory of anchoring new learning material to what already exists in the learner's cognitive structure.

What already exists in the learner's cognitive structure has a great influence on the mastery of new concepts. New concepts are directly or indirectly related to this pre-existing knowledge. So, the most important single factor that has influence in the learning of science is the learner's prior knowledge. The teaching of science can be made more effective if Gagne's learning hierarchy and Ausubel's learning theory are translated into practice. In the words of Ausubel, "if we had to reduce all of educational psychology to just one principle, we would say this - - the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, Novak, & Hanesian, 1978; p.163). Gagne points out the discrepancy in the present system of education - - "it is, in fact, the existence of prior capabilities that is slighted or even ignored by most of the traditional learning prototypes. And it is these prior capabilities that are of crucial importance in determining the conditions required for subsequent learning" (cited in Ausubel, Novak, & Hanesian, 1978; p.168).

Chemistry is a subject composed of sets of organised rules which build on each other which may be represented as a learning hierarchy.

A hierarchy is an arrangement of tasks or items into a pattern that shows the pre-requisite and relationships among them. So, while teaching a concept, the teacher should be aware of the pre-requisites of that concept which the teacher intends to teach. If students have sufficient pre-requisite knowledge for learning a particular concept, then, it is easy for the teacher to link it with students' prior knowledge which helps to understand the concept properly, thus providing a better retention. For example, 'chemical equilibrium' is a concept in chemistry. For learning this concept, the pre-requisites are - - forward reaction, backward reaction and reaction rates. If pupils are not familiar with these pre-requisites, then, it is not of much use to teach them the concept of chemical equilibrium directly because they will fail to get it in their cognitive structure. So, it is very important to test the pre-requisite knowledge without which learning cannot be effective and permanent.

Pre-conceptions

The most fundamental problems confronting today's cognitive psychologists are two - - (1) how to represent the knowledge that a person has and (2) how to identify the mechanisms by which a person uses this knowledge. Mere pre-requisite knowledge will not help in meaningful learning. Pupils must know the relevance of the pre-requisites in learning a new concept. Most of the new materials that our pupils encounter in schools are substantively associated to a previously learned background of meaningful ideas and information. Ausubel is of the opinion that the curriculum often is deliberately organised in this fashion to provide for easy introduction of new facts, concepts and proposition (Ausubel, et al., 1978).

Prior learning will not become pre-requisite unless it is incorporated into new learning. This incorporation of prior knowledge is possible through proper teaching methods. The pre-requisites should be properly determined before teaching a difficult concept. The difficult or complex concept may be composed of simpler or less complicated concepts or rules, which might have already been learnt by pupils. "Certain previously learned capabilities provide necessary support for new learning, regardless of what is being learned" (Gagne, 1976, p. 267). When the intellectual skill of adding integers is learned, the previously acquired skill of subtracting whole numbers is incorporated as part of the new capability. He is of the opinion that certain intellectual skills, often those learned years ago, may be seen to give support to the learning of other kinds of capabilities.

Relevance of pre-conceptions

Gagne defines the term pre-requisite as a capability of prior learning which is incorporated in new learning; the previously learnt entity actually enters into newly learned capability, becomes and remains a part of the behaviour which results from the events of learning (Gagne, 1977). However Ausubel and Gagne were thinking only in terms of the facilitative effects of prior knowledge. Now, there is a growing interest in the notion that students do posses 'invented ideas' based upon their interpretations of sensory impressions which influence the ways in which they respond to and understand the disciplinary knowledge as presented in the classroom (Driver & Erickson, 1983). This understanding mainly stems from a 'constructivist epistemology' (Driver, 1982; Osborn & Wittrock, 1983) in which it is assumed that learners actively generate meaning from experiences. Students learn generally in the context of their previous experience. Dewey (1956) maintained that an educational experience which stimulates development is the one which arouses interest, enjoyment, and challenge the 'immediate experience' of the student. Therefore, any teaching style or model should start with what students know.

Planning of instruction and prerequisites

In lesson planning, there is a step known as identifying the previous knowledge or pre-requisite. The previous knowledge is identified as something the students have learned in the previous class or during their study of the subject in the previous year. Student-teachers are encouraged to link the new content with the identified pre-requisite knowledge. The teacher-educators do not even alert the student-teachers about the possibility of interaction between new content and pre-requisite knowledge in unanticipated ways. Students have many common-sense beliefs about phenomena which are not in agreement with the way in which these phenomena are interpreted in school science. For example, when a boy pushes a wall, it shows a tendency to move. But this proposition of 'tendency' is not acceptable to an average high school student.

Researchers have also investigated about the concept of 'gas.' They found that pupils do not initially be aware that air and other gases possess material character. For example, pupils regard air and smoke having transient character similar to that of 'thoughts' (Driver, Squires, Rushworth, & Wood-Robinson, 1994). When pupils observe a solid changing into liquid, pupils may think that it loses weight or mass. Stavy presented pupils with two samples of ice having identical weights. She melted one sample of ice and then interviewed pupils about the relative weights of the two samples. Only 50% of pupils at the ages of five and six believed that the weight (or mass) is conserved. However, 50% students at the age of seven and 75% students at the age of ten believed that the mass is conserved in both cases (cited in, Driver, et al., 1994). Another example is that of air and air pressure. School children of the age 12-16 think that only wind, and not still air, has pressure.

Several cognitive psychologists have proposed that internalisation (selection, perception and interpretation) of new information and ideas by a person are a function of his/her existing conceptual framework (e.g., Piaget, 1964). Pre-conceptions often interfere with intended learning outcomes. When a student retains and continues to use his/her pre-conception to interpret classroom information, s/he is likely to give it meaning which differs from or even conflicts with the meaning intended by his/her teacher. It is possible that the learner is not even aware of this gap and that s/he is perfectly satisfied with his/her own interpretation, thinking that such was also his/her teacher's intention. The teacher too can be totally unaware of how the student has internalised the new information. The teacher often attributes a wrong answer to a question as students' 'not understanding' but the fact is that students 'understand the content differently' from what was intended (Piaget, 1964).

The process of interaction of learner's naive pre-conception and that of scientist's accepted conception and subsequent internalisation is termed as 'accommodation' in Piaget's theory. That is, in accommodation, student's mind modifies his/her pre-conceptions to reach consonance with the accepted scientific conceptions. Pre-conceptions might undergo partial or radical modifications. The degree of cognitive accommodation demanded from a student in studying science varies with the subject studied and with the nature of the students' pre-conceptions (Nussbaum & Novick, 1982). It is suggested that a psychological state variously called as "disequilibrium" or 'cognitive dissonance' or 'conceptual conflict' should be created to seek more knowledge in order to relieve such a state. Nussbaum and Novick (1982) suggested that demonstrations are not compelling forces to create the conceptual conflict.

Research on the role of students' pre-instructional conceptual framework in learning science has revealed that the science instruction very often has rather limited success. A review of research literature shows that several terms have been used to denote students' pre-instructional conceptual frameworks. They are - - pre-conceptions (Anderson & Smith, 1983), phenomenological primitives (diSessa, 1983), intuitive ideas (Mc Closkey, 1983), children's Science (Osborne, Bell & Gilbert, 1983), alternative frameworks (Driver & Easley, 1978; Saxena, 1997), naive beliefs (Caramazza, Mc Closkey, & Green, 1981), misconceptions (Ausubel, 1966), and mini theory. Of the above mentioned conceptions, only pre-conceptions and misconceptions are discussed here:

1. **Pre-conceptions:** Students have primitive notions about objects and phenomena which stand without significant explanatory substructure or justification. Such explanatory elements are called pre-conceptions. For example, consider a man standing at rest with a load on his head. For a learner the man is doing some work, but in scientific terms he is not doing any work. In this context the learner has a preconception that the man is doing work. Another example is the 'resistance' offered by a conductor. The word meaning of resistance is 'the ability of a body to resist.' However in current electricity, the term resistance is used to denote that the number of available free electrons is not adequate

in a material for the flow of electric current. Here, there is no obstruction caused to the flow of current, which is a pre-conception of the learner associated with the vocabulary - 'resistance.' Pre-conceptions originate from different sources such as lived-experiences, use of language, interaction with objects and people, etc.

2. **Misconceptions:** This refers to incorrect conceptions when viewed from the scientific point of view which have been formed by science instruction itself. For example, while using a still model of an atom for teaching structure of atom, the teacher may induce the learner to think that there are rigid paths around the nucleus or that the electrons are stationary. Use of colour chalks to draw electronic structure the teacher may use, say red colour to denote the electrons in the K shell and blue to denote the electrons in the L shell, this may induce the learner to think that electrons in the K shell are different from that in the L shell.

Role of teacher in the constructivist paradigm

Recent studies have highlighted the importance of teachers understanding how children learn. To teach children successfully, teacher requires an understanding of how children think and construct scientific knowledge as well as a thorough understanding of science (Alsop, 2003). Since children's existing ideas have a major influence on learning, it is necessary that the teacher should be sensitive to his/her pupil's ideas. If teachers are aware of some possible views held by children at various age levels, then they can devise appropriate ways to ascertain different views held by their pupils (through the use of questionnaires, informal discussions or interviews). As a medical practitioner diagnoses the cause of a symptom before attempting to alleviate it, so the teacher needs to diagnose the viewpoints of her/his pupils before deciding how to set about modifying them towards more scientifically acceptable ones. Where pupils' views are completely unknown, an awareness of the significance of pupil's views can in itself lead to the discovery of some important factors in children's present thinking about the topic concerned. For this to occur regularly, however, a systematic recording of interesting comments made by pupils in the class will have to be analysed.

It is usually not possible, in ordinary class interactions, to explore any one pupil's ideas in depth. However, small changes in emphasis by the teacher can assist here. For example, when an inappropriate or unexpected answer is provided by a pupil in a teacher-led discussion, a few moments can be spent attempting to find out why the pupil gave that answer. So, often in class, the inappropriate answer is ignored and the teacher moves the question on to another pupil in constant pursuit of the 'right' answer. To discover or to diagnose children's existing knowledge, teachers must provide plenty of opportunities for pupils to express their ideas, whether in small groups or in whole-class settings. However, this in itself is not enough. Teachers, need to ensure a classroom climate where children's ideas are valued and listened to. The role of teacher as listener is inherent in the role of 'teacher as diagnostician' (Osborne & Freyberg, 1985).

Learner and constructivism

"The psychological theory of constructivism came from Jean Piaget and Lev Vygotsky. The theory of constructivism has led to a debate between those who place more emphasis on the individual cognitive structuring process and those who emphasise the social effects on learning" (Fosnot, 1996, p. 23). The terms 'cognitive constructivism' and 'social constructivism' have become common when talking about psychological theories of the new concept of learning.

Along with the previous psychologists mentioned, Bruner (1961) had a big influence on the theory of constructivism. Bruner's major idea was that learning is an active social process; in which students construct new ideas or concepts based on their current knowledge. He also suggested that the teacher should motivate and encourage students to discover principles by themselves.

Cognitive Constructivism

Cognitive constructivism is based on the work of developmental psychologist Jean Piaget. Piaget's theory has two major parts - - (1) 'ages and stages', which predicts what children can and cannot understand at different ages, and (2) a theory of development that describes how children develop cognitive abilities. The theory of development is the major foundation of cognitive constructivist approaches to teaching and learning. Piaget's theory of cognitive development suggests that humans cannot be 'given' information which they automatically understand and use, they must 'construct' their own knowledge. They have to build their knowledge through experience. Experiences allow them to create mental images in their head. Cognitive prospective theories focus on both what students learn and the process by which they do so (Fosnot, 1996).

The role of the teacher and the classroom environment are important parts of Piaget's theory. The role of the teacher is to provide a classroom, full of interesting things to encourage the child to construct their own knowledge and to have the ability to explore. The classroom must give the students the opportunity to construct knowledge through their own experiences. They cannot be 'told' by the teacher. There is less emphasis on teaching directly specific skills and more emphasis on learning in a meaningful context.

Social Constructivism

Social constructivism is a theory developed by psychologist Lev Vygotsky. Vygotsky's theory is very similar to Piaget's assumptions about how children learn, but he places more emphasis on the social context of learning. In Piaget's theory, the teacher plays a limited role whereas in Vygotsky's theory the teacher plays a very important role in learning. There is much more room for an active, involved teacher. Social constructivism argues that students can, with help from adults or children who are more advanced, grasp concepts and ideas that they cannot understand on their own. Unlike cognitive constructivism, teachers in social constructivism do not just stand by and watch children explore and discover. The teacher may guide students as they approach problems, may encourage them to work in groups, ask a question to think about issues, and support them with encouragement and advice.

Social constructivism views each learner as a unique individual with unique needs and backgrounds. The learner is also seen as complex and multidimensional. Social constructivism not only acknowledges the uniqueness and complexity of the learner, but actually encourages, utilises and rewards it as an integral part of the learning process (Wertsch, 1997). Social constructivism encourages the learner to arrive at his/her own version of the truth, influenced by his/her background, culture or embedded world view. Historical developments and symbol systems, such as language, logic, and mathematical systems, are inherited by the learner as a member of a particular culture and these are learned throughout the learner's life.

Vygotsky (1988) suggested that children learn not so much in terms of what they can do on their own but rather, in terms of what they can achieve when they are given help. In this context, Vygotsky coined a term 'Zone of Proximal Development' (ZPD). Vygotsky (1978) clarified the ZPD as 'the distance between the actual development level as determined by problem solving and the level of potential development as determined through problem solving under the guidance or in collaboration with more capable peers' (p. 86). The proposition is that we should provide opportunities for our pupils to engage in scientific activities in advance of their current individual achievements but within the boundaries of ZPD. In this context, the term 'scaffolding' has been used to describe the role of teaching. During scaffolding, the teacher does not adjust the task but offers support and guidance in such a way that the learners are able to extend their intellectual range. Scaffolding can take different forms such as - - (1) highlight important features of the task, (2) make the task meaningful in terms of what the pupils' already know, (3) establish a familiar context for the task, and (4) split a task into a series of manageable stages or reduce the mathematical or linguistic complexity. Further, a task can be made emotionally and socially appealing, reducing stress and anxiety and creating the classroom environment that is supportive and conducive of learning. As the competence of the child increases, the teacher needs to gradually remove the support (or scaffold) and the timing of this is both sensitive and crucial. A detailed description of the theory is beyond the scope of this book.

Chapter VIII

PLANNING OF INSTRUCTION

Planning is very important in instruction as in any enterprise. Adopting a top-down planning strategy, there are three levels to the planning of instruction. The plan of instruction for a particular academic year of a particular subject is decided at the beginning of the year. There are several factors that are to be considered in the process of planning. Based on the plan of instruction for the whole academic year, unit and lesson plan are developed. Thus, planning of instruction has three levels. They are - - (1) Year Plan, (2) Unit Plan and (3) Lesson Plan. Each of these is detailed below.

Year Plan

A year plan is a plan for an academic year. Based on the number of working days in each term (quarter) the number of class periods available to teach a particular subject is estimated. The time that will be spent on co-curricular activities, vacations in each term, local holidays, study holidays and examination days are to be taken into account. Then, the time available is distributed among the different units (chapters) included in the syllabus. Thus, the year plan stipulates the time available (in number of class periods) to teach each unit, the month in which each unit will be taught and the relative weightages to the instructional objectives in each unit. Teachers of the same faculty can sit together and decide on the year plan. However, the termly and annual examinations are conducted as per the schedule of teachers' unions and there is no scope for any such school-based decision. Thus, teachers are not directly involved in the development of a year plan. Teachers get the year plan to be implemented and their job is made easy. It is desirable to have a year plan for each school taking into account the peculiarities of the school. Different formats for year plan are given below.

Year Plan

(based on the seven instructional objectives)

Subject : Standard :

School : Year :

No.	Unit	Month	No. of class periods	%	Objectives in percentage						
					1*	2*	3*	4*	5*	6*	7*
1											
2											
3											
4											
5											

1*. Knowledge 2*. Understanding 3*. Application

4*. Skills 5*. Interest 6*. Attitude 7*. Appreciation

An alternate format for the year plan proposed by the State Council of Educational Research and Training includes details of classroom and outside classroom activities. It also indicates different resources/learning materials to teach the unit. The unit to be taught in each month is indicated in this format. A sample of the format is given below.

Year Plan

Subject : Standard :

School : Year :

No.	Month	Unit	Classroom Activities Activities		Outside Classroom		Remarks
			Activities	Resources	Activities	Resources	
1	June	Heat	Experiment, Discussion	Thermometer, different liquids, ice,	Field trip to …	Freezer,	
2	Jul.						
3	Aug.						
4	Sept.						
5	Oct.						
6	Nov.						
7	Dec.						
8	Jan.						
9	Feb.						
10	Mar.	Revision					

A table showing the period distribution for different Units will also help in the year plan. The total number of periods available in a year is estimated on the basis of two periods per week and a total of 32 weeks for instruction. The format for the period distribution is given below.

Standard X

Subject: Physics

Distribution of Periods

Sl. No.	Chapters	No. of Periods
1	Heat	6
2	Heating effect of electricity	8
3	Electromagnetic Induction	10
4	Electric power generation and distribution	10
5	Light	8
6	Nuclear Physics	6
	Total	48

Unit Plan

A unit is a mutually related content area. According to Preston, "A unit is a large block of related subject-matter as can be overviewed by the learner" (cited in Sharma & Sharma, 1971). It may consist of several sub-units or topics. A unit is organised in such a manner so that each lesson plays a role in the development of the unit. Unit planning is an important aspect in the planning of instruction. One of the importances of a unit plan is that it breaks up the year's work into small sections which students can understand and overview (Thurber & Collette, 1964). It is argued that most students work better on a series of short tasks than on a few large ones. The purpose of the task is better understood when the task is smaller.

A unit plan can have all the elements of a lesson plan. But for practical reasons, different authors have suggested different formats for the use of teachers. The simplest format for unit plan includes the name of the unit with time allotted, major objectives, learning outcomes and evaluation items (Thurber & Collette, 1964). The unit plan suggested by Soman (1987) includes general information such as subject, standard, time, introduction, pre-requisites, objectives and specifications, teaching aids, learning experiences and evaluation items.

The unit plan must invariably include the pre-requisites relevant to each unit which will help in the preparation of the class. Referring to the year plan, the teacher can have an idea about the time allotted to teach a particular unit. The demonstrations and explanations should be arranged in such a way so as to finish the unit in the prescribed time. While teaching, the weightages to be given to each objective should be borne in mind. The learning experiences should satisfy the requirements for realising different objectives in their respective weightages. An idea about the weightages to be given to the different objectives will be given in the year plan. A unit plan has the following eight sections:

1. General information
    a. Subject
    b. Standard
    c. Unit
    d. Time (in class periods)
2. Content overview (a brief summary of the unit)
3. Pre-requisites (which will be used in the introduction of the unit)
4. Statements of instructional objectives with items of content analysis.
5. Teaching Aids.
    a. Glass wares/Instruments
    b. Chemicals/Consumables
    c. Improvised Apparatus/Charts/Models
6. A three column format with content, objectives with specification and learning experiences.
7. Evaluation items

8. Home Assignments

   a. Written assignments

   b. Activity Assignments

A Sample Unit Plan

A sample unit plan is given below. Only sample items in each category are given and it is not complete.

1. General information

a. Subject: Chemistry

b. Standard: VIII

c. Unit: Energy changes in chemical reactions

d. Time: 7 class periods

2. Content overview

Exothermic reactions – endothermic reactions – pyrotechny – photochemical reactions – chemistry of photography – phosphorescence – electrochemical cell – electrolysis of acidified water - electroplating

3. Pre-requisites

The pupil knows that matter undergoes physical and chemical changes.

4. Statements of instructional objectives

I. The pupil acquires knowledge about the following terms, facts and equations.

Terms: (1) Exothermic reactions

(2) Endothermic reactions

(3) Thermo chemical reactions

(4) Pyrotechnic mixture

(5) Phosphorescence

(6) Photochemical reactions

(7) Electrochemical cell

(8) Electrolysis

(9) Electrochemical reactions

Facts: (1) Magnesium burns in air to give magnesium oxide, heat and light

(2) Sodium hydroxide combines with hydrochloric acid to give sodium chloride, water and heat

(3) Magnesium reacts with hydrochloric acid to give magnesium chloride, hydrogen and heat

(4) Nitrogen and hydrogen combine to give ammonia and heat

(5) Ammonium chloride dissolves in water absorbing heat

(6) Ammonium nitrate dissolves in water absorbing heat

(7) Potassium nitrate dissolves in water absorbing heat

(8) Water gas produced by passing steam over red hot coke in the presence of heat, etc.,

Equations: (1) $2\,Mg + O_2 \rightarrow 2\,MgO + Heat$

(2) $NaOH + HCl \rightarrow NaCl + H_2O + Heat$

(3) $Mg + 2\,HCl \rightarrow MgCl_2 + H_2 + Heat$

II. The pupil develops understanding about the above mentioned terms, facts, and equations and the following concepts and definitions

Concepts: (1) Heat energy is liberated in exothermic reactions

(2) Heat energy is absorbed in endothermic reactions.

(3) Electricity is produced by electrochemical reactions

(4) Metals can be purified by electrolytic decomposition, etc.,

Definitions: (1) Exothermic reaction – Reactions in which heat and other forms of energy are liberated are called exothermic reactions.

(2) Endothermic reactions – Reactions in which heat energy is absorbed is called endothermic reactions, etc.

III. The pupil applies the knowledge and understanding about various types of energy changes in reactions in new (unfamiliar) situations such as

(1) Sodium reacts vigorously with water and bursts into flame

(2) Melting of ice

(3) Storage of certain medicines in coloured bottles, etc

IV. The pupil develops skill in observation in reactions such as (list a few important reactions that will be demonstrated)

V. The pupil develops interest in reading about compounds that give colour to flames in fire works

VI. The pupil develops scientific attitude in recording and interpreting data honestly.

VII. The pupil develops appreciation about the different uses of chemical reactions.

5. Teaching Aids

A. Glass wares/apparatus

(i) 20 ml Test tubes

(ii) 100 ml Beakers, etc.,

B. Chemicals/consumables

(i) Magnesium ribbon

(ii) Dilute hydrochloric acid

(iii) Ammonium chloride, etc.,

C. Improvised apparatus/charts/models

(i) For example, a chart showing electroplating of an iron spoon

6. A three column format with content, objectives with specification and learning experiences.

Content	Objective with Specification	Learning Experience
Preparation	K/Recalls	What is a chemical change?
Presentation Mg combines with oxygen giving MgO	U/Infers	$2\ Mg + O_2 \rightarrow 2\ MgO+$ Heat(Demonstration)

7. Evaluation items

(1) What are exothermic reactions? Write two examples.

(2) What are endothermic reactions? Write two examples.

(3) What is water gas? How is it prepared?

8. Home Assignments

a. **Written assignments** – All the important items of content should be covered under the written assignment.

b. **Activity Assignments** – The topic is not suitable for giving activity assignments. However, students may be asked to collect names of some tablets which are preserved in coloured bottles.

The activity-oriented approach to teaching of science and Continuous and Comprehensive Evaluation (CCE) scheme has influenced the modern unit plan. The alternate format is given below.

Format of a Sample Unit Plan

Subject: Chemistry Standard: VIII

Unit: Energy Changes in Chemical Reactions

Time: 7 Class Periods

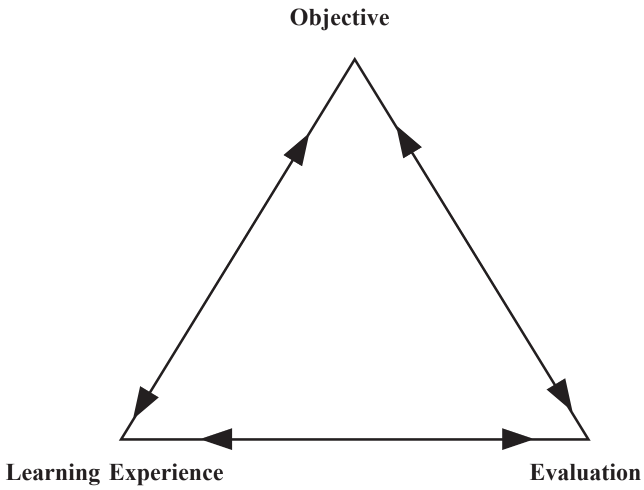
Sl. No.	Curricular Objectives) (Content & Domain	Activities	Learning Materials	Evaluation*					Time in periods
				CT	Pt	Asgmt	C/R	S/P	
1	Through experiment, observation, and discussion pupil identifies the heating effect of electricity	Experiment Discussion	Resistance, Ammeter, Battery, Bulb						one Period

*CT -Class Test Pt – Project Asgmt – Assignment

C/R – Collection/Record S/P – Seminar/Presentation

Triangular Relationship among Objective, Learning Experience and evaluation

Objectives specify the changes to be brought about in the behaviour of the pupil. What changes are to be made is the concern of the teacher before teaching. Objectives of teaching constitute the focal point of any teaching procedure. Objectives tell us what the pupil is expected to do and the conditions under which s/he should perform. Furst (1958) elaborated on the triangular relationship among objectives, learning experiences and evaluation. The objectives are realized by selecting suitable learning experiences. Evaluation is the process to measure the extent to which the contemplated learning experiences were functional in bringing the changes. Also, the learning experiences are designed keeping in view the learning experiences. Thus, the objectives, learning experience and evaluation are interrelated.



The term 'learning experience' refers to the interaction between the learner and the external conditions in the environment to which he can react (Tyler, 1949, p. 41). Learning takes place through the active behaviour of the learner. It is possible for two students to be in the same class and for them to have two different experiences. However, the teacher can provide an educational experience through setting up an environment and structuring the situation so as to stimulate the desired type of reaction. The nature of the learning experiences is determined by the objective. In other words, **learning experiences are objective-based**. So, developing learning experience to achieve the objective is the second stage in the process of teaching.

Teacher has to assess how far the learning experiences have been successful for the attainment of the pre-determined objectives. This is the task of evaluation. For example, a doctor gives certain medicine to a patient and observes the effect of the medicine and determines whether s/he should continue it or change it. Like wise, a teacher should monitor the progress of the learner. Here, progress is measured in terms of the objectives. Thus, the objectives, learning experience and evaluation are interdependent and inseparable. That is, the objectives are realised through learning experience, and learning experiences are planned to achieve the objectives. The effectiveness of learning experience is evaluated and the evaluation is done in terms of the objectives. Thus, evaluation is also related to the learning experience and objectives. The interdependency of objectives, learning experience and evaluation is represented as a triangular relationship as shown above.

Lesson Plan

Careful planning of classroom lessons is the key to successful teaching (Thurber & Collette, 1964). A lesson plan gives direction to the teacher (Das, 1985). The term lesson is interpreted in different ways by different people. Generally, teachers take it as a work to be covered in a class period which runs for about 40 minutes (Gupta, 1985). About half a century ago Good (1945) defined a lesson plan as a teaching outline of the important points of a lesson arranged in the order in which they are to be presented which may include objectives, points to be made, questions to ask, references and assignments.

The importance of lesson plan has been detailed by many authors (e.g., Joseph, 1982; Sharma, 1996). However, research findings suggest that teachers have three reasons for lesson planning (Clark & Peterson, 1990; pp 70-71). They are: (1) planning to meet immediate personal needs (e.g., to reduce uncertainty and anxiety, to find a sense of direction, confidence and security); (2) planning as a means to the end of instruction (e.g., to learn the material, to collect and organise materials, to organise time and activity flow); and (3) planning to serve a direct function during instruction (e.g., to organise students, to get an activity started, to aid memory, to provide a framework for instruction and evaluation).

Apart from the three reasons, there are several variables that influence the lesson planning, viz., locality of the school (urban/rural), number of students in the class, students' previous knowledge assumed by the teacher, resources available at the school, etc. (Gupta, 1985). Therefore, there can be as many lesson plans as there are teachers on a single topic (Joseph, 1982). One way to think of a lesson is by using the analogy of story which is highly organised; it has a beginning, a middle and an end (Stigler & Stevenson, 1991). A good story engages the reader's interest in a series of interconnected events which are best understood in the context of the events that precede and follow it.

The published curriculum (text book) is transformed in the planning process by additions, deletions, changes in sequence and emphasis, teacher's interpretations and misunderstandings (Clark & Peterson, 1990). Novice teachers seem to be reluctant in making changes in the process of planning. For example, a text book may contain a concept (e.g. alkali metals are highly reactive) for which there is no fact given. In such cases, the teacher will have to create (add) two or more facts that will lead to the concept. However, to a greater extent teachers (both novice and experienced) are influenced by the published curriculum material (text book) in the lesson planning. The process of planning is restricted by the prescribed content in the text book. Teacher-educators should encourage teacher-trainees to make necessary changes demanded by the method and context.

Steps in Lesson Planning

Lesson planning is associated with the name of John F. Herbart (1776-1841). Herbart's theory of education is based on the assimilative function of mind. This assimilative power of mind to him is the apperception. Apperception implies the linking up of new experiences with the old (Purkait, 1995, p.183). The principle of apperception suggests two important processes in learning, viz., absorption and reflection. Absorption stands for clearness and association, and reflection involves system and method. Thus, Herbart suggested four steps in the educative process. They are - - (1) clearness, (2) association, (3) system and (4) method. Later, Herbart's disciple, Ziller, divided the step clearness into two - preparation and presentation. The other three steps were renamed (Purkait, 1995, p. 184). Thus, the five steps of lesson planning are - - (1) preparation, (2) presentation, (3) association/comparison, (4) generalisation/systematisation and (5) application (Ozmon & Craver, 1986, p. 49). However, several authors have added recapitulation to make six Herbartian steps in developing a lesson plan (e.g., Maitra, 1991; Kohli, 1986; Joseph, 1982). The main problem in delineating the Herbartian steps is that none of the authors have indicated the source from which they have drawn this information. However, the process of lesson planning centres around the six Herbartian steps - - (1) preparation or introduction, (2) presentation, (3) association or comparison, (4) generalisation or systematisation, (5) application and (6) recapitulation. Each step is detailed below.

1. Preparation/Introduction

According to Herbart, the mind of the child must be prepared to receive the knowledge. It is just like preparing land before sowing the seed (Kohli, 1986, p. 91). There are several techniques to prepare students for learning. The technique or activity depends on the nature of the content area and the learning experiences. Maitra (1991) has listed four methods to prepare students for learning. They are - - (1) asking questions related to previous knowledge, (2) narrating a story related to the topic, (3) arousing curiosity by presenting a bit of unknown facts and (4) doing an experiment leading into the lesson. Das (1985) suggested that the preparation stage should culminate in the announcement of the day's lesson. A few teacher-educators even insist on writing the title of the day's lesson on the chalk board. There is no uniformity in the practice and may be unnecessary in some cases.

2. Presentation

The content of the lesson is presented at this stage in a manner that will facilitate meaningful learning. The inductive method and a spirit of heurism coupled with thought provoking questions should pervade the classroom. This will help students engage in the learning process. A chalk board summary would help students organise the new material in their mind. Each experience should have a logic in the sequence and appropriate media and methods should be selected in the presentation.

3. Association/Comparison

Learning becomes permanent when the new knowledge is associated with already known facts, concepts and experiences. Isolated bits of information are easily forgotten. A number of possible connections should be made by giving examples and recalling ideas that students already know and that will have bearings on the new content. Comparisons initiate reflective thinking which may result in inductive and analogical reasoning. Probing questions help in the process of association and comparison. These mental processes will lead into classification and generalisation.

4. Generalisation/Systematisation

Generalisation is the process of abstraction. This process of generalisation/systematisation helps the learner to develop an understanding about a group/class of objects/events. The generalisation arrived by inductive method can be used further (deductively) to infer the quality/property of a new object which belongs to the same group. This will be elaborated under induction and deduction in chapter V

5. Application

The knowledge and understanding developed by a student is valuable only if s/he can use them in unfamiliar situations. The generalisation arrived in the previous stage should be validated by extending it to novel situations. The application stage gives the learner an idea about the worth of the knowledge and makes learning more clear and meaningful.

6. Recapitulation

Recapitulation is the last step in the sequence of Herbartian steps. In recapitulation, the knowledge, understanding, application and skill involved in the content area are tested/reviewed using appropriate test items. This will help both the teacher and the student in evaluating the effectiveness of teaching and learning.

The Herbartian steps described above are basic to lesson planning. However, it need not be followed rigidly. For example, in some cases, the application stage may be more suitable after a review of what students have learned. Vaidya (1971) is very critical about the rigid steps in lesson planning. He states, "There is no Money Order form like proforma for writing up the lesson plan" (p. 168). He lists fourteen parts to a lesson plan with freedom to pick and choose as there is no agreed format. However, a proforma evolved as a result of a State

Level Workshop held at Peet Memorial Training College, Mavelikara, Kerala in 1995 is given below.

There shall be ten steps in the development of a lesson plan. They are:

(1) General Information

(2) Content Analysis

(3) Statements of Instructional Objectives

(4) Pre-requisites/Previous Knowledge/Entry Behaviour

(5) Teaching Aids

(6) Preparation/Introduction

(7) Presentation

(8) Application

(9) Review/Recapitulation and

(10) Assignments. Each step is detailed below.

1. General Information

General information includes details such as name of teacher, name of school, standard and division, strength, subject, unit, lesson unit, date and duration.

2. Content Analysis

Content analysis is an important step in the planning of a lesson. However, only a few authors (e.g., Nair, 1982) have discussed the importance of content analysis. And the discussion on content analysis is surprisingly inadequate. Most of the books available on science teaching have analysed the content into four categories viz., terms, facts, concepts and principles. A detailed analysis of content area is very important in developing appropriate instructional sequence. Also, a type of activity/experience rests on the items in a content area.

A detailed content analysis of physical science (physics and chemistry) will reveal that the four categories (terms, facts, concepts and principles) are quite insufficient to analyze the content exhaustively. Therefore, the following twelve categories are created to do a better job of content analysis. The categories are - - (1) symbols, (2) terms, (3) facts, (4) formulae, (5) equation, (6) concepts, (7) definitions, (8) conventions, (9) hypotheses, (10) laws, (11) principles (12) theory and (13) processes. It may be necessary to generate more categories and the list is not claimed to be exhaustive. Each of the thirteen items is detailed below with suitable examples.

(1) Symbols: A symbol is something that stands for the idea, an expression, a quantity or a mathematical operation not intrinsically suggested by its form or character (Good, 1945). In chemistry, a symbol is a letter(s) representing an atom of an element. For example, 'S' is the symbol for sulphur and 'g' stands for acceleration due to gravity.

(2) Terms: A term is a new word having significant meaning to the pupil. The term can be a scientific term or a technical term. For example, calorie, mechanical advantage, potential energy, chemical equilibrium, etc.

(3) Facts: A fact is a reality, a real state of a thing which is almost always demonstrable. According to Conant, a fact must be directly observable and must be demonstrable (cited in Thurber & Collette, 1964). For example, magnesium reacts with hydrochloric acid giving magnesium chloride and hydrogen; copper conducts electricity.

(4) Formulae: A formula is an algebraic statement of a rule for computation or a computational law expressed in symbols (Good, 1945). Formulae can also be considered as a statement of facts in symbolic or general form, by substitution in which a result applicable to particular data may be obtained. It can also be a chemical formula of a compound such as HCl.

For example,

$$G = \frac{m_1 m_2}{d^2}$$

(5) Equation: An equation is a statement of the equality of two or more quantities. For example, the lens equation, $1/f = 1/u + 1/v$. Chemical equations are representation of reactions in terms of symbols and formulae of the elements and compounds involved.

For example, $NaOH + HCl \rightarrow NaCl + H_2O + Heat$

(6) Concepts: A concept is defined as "an abstraction from observed phenomena; it is a word that states the commonalities among those observed objects or events and distinguishes the phenomena from other objects or events" (Mc Millan & Schumacher, 1989; p. 94). A concept is a classification of objects, events or ideas into a set by abstracting the common essential characteristics which defines that set. Thus, a concept is a generalized idea built upon several facts. For example, a concept such as heat expands metals is a generalised idea arrived at from two or more facts, viz., heat expands copper and heat expands iron.

(7) Definitions: A definition is a statement of the meaning to be attached to a word, expression, operation or symbol. For example, the definition of the term 'ionization potential' is that it is the minimum energy required to release the most loosely held electron from a single, neutral, gaseous atom. Similarly specific gravity, isotope, calorie and other such terms can be defined.

(8) Conventions: A convention is an established usage taken as an arbitrary sequence which is in popular use. A convention is not essentially logical or having anything scientific in it. For example, focal length of a convex lens is taken to be a positive value and that of a concave lens is taken as a negative value.

(9) Hypotheses: A hypothesis is a supposition put forward in explanation of observed facts. It is a proposition put forth as probably true but requiring further investigation or experimentation. For example, it is hypothesised that earth acts as a magnet.

(10) Laws: A law is a formal statement of the manner or order in which certain natural phenomena occur under specified conditions. For example, in Boyle's law, the condition is that at

constant temperature, the pressure of a given mass of gas is inversely proportional to its volume.

(11) Principles: A principle is a general statement which establishes the relationship between at least two concepts. For example, Archimedes principle states that when a body is partially or fully immersed in a liquid, the loss of weight experienced by the body is equal to the amount of liquid displaced. There are two major concepts involved in the principle. They are - - (1) loss of weight experienced by a body immersed in the liquid and (2) the amount of liquid displaced by a body immersed in the liquid. The relationship between the two concepts is stated in the Archimedes principle.

(12) Theory: A theory is a general rule or system of relationship advanced as the explanation of observed events or natural phenomena. It is a logically deduced construct isolated from its application. For example, Bohr's theory of atom.

(13) Processes: A process involves a series of facts (operations) which will have a sequential order of occurrence, which are standardised and accepted. For example, the procedure for the laboratory preparation of hydrogen sulphide involves use of Kipp's apparatus, chemicals such as ferrous sulphide and dilute hydrochloric acid in designated bulbs; which should follow a sequential order.

The categories given above are not mutually exclusive, since a principle involves concepts and facts at the concrete level. A disclaimer is in order, that is, the categories listed here are typically useful to physical science and may not be useful to other subjects. Also, other categories may have to be generated for doing a thorough content analysis of subject areas other than physical science. A critical and detailed analysis of content is crucial for the teacher to sequence the learning experiences (activities) and budget the time required in developing a lesson. The arbitrary nature of curricular objectives and specifications can be reduced to a greater extent by proper content analysis.

3. Statements of Instructional Objectives

These are statements about the expected behavioural changes in the pupil. Each statement should include only one objective. The statements should be written in terms of the expected behavioural changes in the pupil. There should be two parts to each statement of instructional objective, one pertaining to the behavioural change and the other related to the content item.

4. Pre-requisites/Previous Knowledge/Entry Behaviour

Of the three terms, the term pre-requisite is more appropriate for it focuses on the required previous knowledge/entry behaviour without which the teacher cannot proceed. It is crucial in the development of a lesson to isolate the pre-requisite from where the class should begin. The pre-requisite is not necessarily something that the student has learned in the previous class(es). It can be an experience or an anecdote. The purpose of identifying the pre-requisite is to start the lesson from where the students are. It also helps in arousing the apperception mass thereby motivating the students to learn.

5. Teaching Aids

The list of teaching aids should be written comprehensively. General statements such as 'usual classroom aids' should be avoided. It is desirable to prepare the list of teaching aids under three subdivision viz., (a) Glasswares/Instruments, (b) Chemicals/ Consumables and (c) Improvised Apparatus/Charts/Models. The improvised items, models and charts should be described in one or two sentences to get an idea about the item.

6. Preparation/Introduction

The preparation stage is detailed under the Herbartian steps in the previous pages and is not reproduced here.

7. Presentation

The details of presentation are described under the Herbartian steps in the previous pages.

8. Application (wherever appropriate)

The step is comparable to the Herbartian step and is described in the previous pages.

9. Review/Recapitulation

The content presented is reviewed using appropriate items. The order of review can be altered if that will help the application stage.

10. Assignments

Assignments are of two types - - (1) written assignments and (2) activity assignments. Written assignments are intended basically to review the content area. It may contain items that require long answers and drawing of diagrams which cannot be given as seat-work because of time constraints. Activity assignments are designed to engage students in activities that will enable them to work with their hands, to develop manipulative and observational skill which will contribute to the development of scientific hobbies. The assignments should be so designed that it will cater to the needs of the below average, average and above average students. The materials and facilities available in an average home should be taken into account while giving activity assignments.

Several alternatives and parallel formats have been suggested by different authors for lesson planning. For example, Tyler (1949) suggested a linear model with four steps - - (1) specify the objectives, (2) select learning activities, (3) organise learning activities and (4) specify evaluation procedures. Thurber and Collette (1964) added three items, viz., materials, references and assignments to what Tyler had suggested. Different format for the body of the lesson plan such as matter and method (Das, 1985), teaching point and teacher-pupil activities (Maitra, 1991) and matter, method and black board summary (Kohli, 1986) have been proposed. However, a four column format with content, specification, learning experience and evaluation was popular in the State of Kerala until 2001. A sample lesson plan in the four column format is given in Appendix III.

In spite of the different format and stages in lesson planning, the fact remains that the lesson plan is the real plan to be executed in a class period. The unit plan is the reference for developing a lesson plan with respect to time allotted and weightages to be given to different instructional objectives.

Lesson Types

Lesson types can be construed from several perspectives. Dunkin (1987) analysed lesson formats from the point of view of classroom communication and interaction. Wittrock (1986) summarised the complexity of classroom events and the demand on the teacher in group lessons. A few teacher educators think of lesson types as lessons that can be taught using different methods. A few others consider lesson types on the basis of the focus of teaching and learning activities, i.e., teacher-centered, student-centered and content-centered. The one that will be discussed here stems from the nature of the content area.

Teacher-trainees often find the development of lesson plan very difficult for they are not systematically exposed to the types of lessons that they will have to plan. A comprehensive and exhaustive description of the types of lesson plans are beyond the scope of what is attempted here. However, four types of content area will be dealt here (Rajan, 1999a). They are - - (1) descriptive type, (2) inductive type, (3) procedural type and (4) logical relationship type. Each type is discussed below.

1. Descriptive Type

In descriptive type, the content is mostly at the factual level. Analysis of content of this type reveals that there are so many facts in the content area with a minimum of concepts. For example, the high school chemistry deals with periodic classification of elements. There are several facts such as number of elements, atomic weight, physical state of elements at ordinary temperature, number of groups, number of periods, etc. The content demands verbal description of the arrangements of elements with the help of a chart. There is little scope for demonstration and most of the content items are facts to be memorised.

2. Inductive Type

Inductive type lessons are typical for they contain a set of facts which lead to concepts and generalisations. Several content area fall under this category. For example, in chemical bonding; two or three compounds such as sodium chloride, magnesium chloride and hydrogen chloride formed by ionic bond are examined. This leads to the concept that atoms donate their electrons to complete octet in the formation of ionic bonds. The content forms a hierarchical sequence which is essentially inductive in nature. Another example will be order of levers; two or three simple machines such as scissors, tongs, see-saw are given to the students. Students are asked to find the position of Fulcrum, Resistance and Effort. From the pattern of the positions of F, R and E, the concept of first order lever can be developed inductively.

3. Procedural Type

In Procedural Type, a standard procedure is detailed in a particular sequence. The content usually contains a few facts to be arranged in a sequence which invariably involve a diagram. For example, laboratory preparation of a gas such as hydrogen sulphide. This involves a chemical equation and a diagram with a procedure to be adopted in the process of laboratory preparation. The number of facts are limited and importance is in the peculiarity of arrangement of (Kipp's) apparatus and how it is used for the purpose. Working of an apparatus such as Rheostat can also be conceived as a procedural type.

4. Logical Relationship Type

In logical relationship type, the content is of higher level involving relationship among concepts. The content can be a principle or a law involving mathematical concepts such as proportionality, equality of variables. More often than not, these content areas are dealt at an abstract level in textbooks and teacher trainees find it difficult to select appropriate learning experience. On several occasions, teacher-trainees resort to deductive approach that cause too much of information processing load on the part of the learner. Much attention is to be paid in helping teacher-trainees in both selecting learning experiences and also in sequencing them. For example, Boyle's Law; the pressure and volume relationship of a given mass of gas at constant temperature can be presented in the form of a table with arbitrary values. This will lead to the inference of the inverse relationship between pressure and volume.

The four types mentioned above entail different levels of planning. That is, the pre-requisite, learning experience, method of instruction, and home assignment have basic differences in the four types. The role of pre-requisite in the Logical Relationship Type is much more crucial than the other types. The selection of learning experience is very simple in all types except the Logical Relationship Type. The method of instruction in the high schools of Kerala was mostly lecture-demonstration, but now activity methods are attempted. The home assignments can have a variety of items in Inductive and Logical Relationship type but Descriptive and Procedural types involve mostly items to be recalled.

Most of the content areas in high school physics and chemistry will fall in either of the above four categories or a simple combination of one or more of the above categories. Teacher-educators will have to identify types of lesson plans in their areas of specialisation and must positively incorporate the types in the discussion of lesson plans. A thorough content analysis and identification of types of lesson plans are essential for an effective pre-service training of the teachers. Although the instructional methods aim at the realisation of objectives, the content types set limitations on curriculum transaction. An awareness of the structure of the content in a way helps for a better preparation of the student-teachers in the task of lesson planning.

An alternate format for lesson plan

The Sarva Shiksha Abhiyan (SSA), a Central Government funded programme was initiated in 2001. The programme aimed at universal enrolment through proper strategy in the teaching-learning process. The universal enrolment was also aimed at universal retention and attainment. Free and compulsory education up to eighth grade was aimed in this project. The approach of SSA can be characterised as process-oriented, activity-based, learner-centred, life-oriented, strategy-enriched and environment-based. The role of science teacher can be redefined as a facilitator, guide and co-learner. The classroom atmosphere is democratic and permissive. The classroom activities are simple, practical and challenging to keep students engaged in the task. Multiple intelligence theory of Howard Gardner (1993) provides a frame work for the learning process and classroom interaction. Multiple intelligence as it denotes has several dimensions. they are -- (1) linguistic intelligence, (2) logical-mathematical intelligence, (3) spatial intelligence, (4) bodily-kinesthetic intelligence, (5) musical intelligence, (6) inter-personal intelligence, (7) intra-personal intelligence, (8) naturalistic intelligence and (9) existential intelligence. The nine intelligences are briefly described below (Armstong, 2001).

(1) Linguistic intelligence - This is the capacity to use words effectively, whether oral or in written. This includes rhetoric, mnemonics, explanation and metalanguage. For example, writer, orator.

(2) Logical-mathematical intelligence - This is the capacity to use numbers effectively and to reason well. This intelligence includes sensitivity to logical patterns and relationships, statements and propositions, functions, and other related abstractions. This includes categorisation, classification, inference, generalisation, calculation and hypothesis testing. For example, scientists and mathematicians have high level of logical mathematical intelligence.

(3) Spatial intelligence - This is the ability to perceive the visual-spatial world accurately and to perform transformations on those perceptions. It includes the capacity to visualize, to graphically represent visual or spatial ideas, and to orient oneself appropriately in spatial matrix. For example, artists and architects have high level of spatial intelligence.

(4) Bodily-kinesthetic intelligence - This is the expertise in using one's whole body to express ideas and feelings and facility in using one's hands to produce or transform things. This includes physical skills such as coordination, balance, dexterity, flexibility and

speed. For example, athletes, dancers and sculptures have high level of bodily-kinesthetic intelligence.

(5) Musical intelligence - This is the capacity to perceive, discriminate, transform and express musical forms. This includes sensitivity to the rhythm, pitch or melody and timbre or tone. For example, composers and performers have high level of musical intelligence.

(6) Interpersonal intelligenc*e* - This is the ability to perceive and make distinctions in the moods, intentions, motivations and feelings of other people. This includes sensitivity to facial expressions, voice, gestures and interpersonal cues. For example, teachers, counsellors and political leaders have high level of interpersonal intelligence.

(7) Intrapersonal intelligence - This is related to self-knowledge and the ability to act adaptively on the basis of that knowledge. This includes self-awareness (one's strengths and limitations), awareness of inner moods, intentions, motivations, temperaments, desires and the capacity for self discipline, self-understanding and self-esteem. For example, psychotherapists and religious leaders have high level of intrapersonal intelligence.

(8) Naturalistic intelligence - This is the expertise in the recognition and classification of the numerous species in the environment of an individual. This includes sensitivity to natural phenomena and interest in plants and animals. For example, naturalists, biologists and animal activists have high level of naturalistic intelligence.

(9) Existential intelligence - This concerns with ultimate life issues. This is the capacity to locate oneself with respect to such existential features of human conditions such as significance of life, meaning of death and the like. To deal with questions of life such as: "Who are we?" "What is it all about?" "Why is there evil?" "Where is humanity heading?" "Is there meaning in life?" For example, theologians, yogis and philosophers have high level of existential intelligence.

Advocates of Multiple Intelligence theory propose that each individual has capacities in all nine intelligences and these intelligences function together in unique ways in each person. Gardner (1993) suggested that if appropriate encouragement, enrichment and instruction are given all the nine intelligences can be developed to a reasonably high level of performance. Also, these intelligences always interact with each other and no intelligence exists in isolation.

Traditional classroom activities do not provide opportunities for students to employ their full range of intellectual abilities. The classrooms are dominated by teacher talk and students are responding to directions of teachers. Jean Jacques Rousseau (1712-1778), Johann Heinrich Pestalozzi (1746-1827), Friedrich Froebel (1783-1852), Maria Montessori (1870-1952) and John Dewey (1859-1952) were all advocates of learning through experiences (Ozmon & Craver, 1986; Purkait, 1995; Pollard, 1997). Needless to repeat the fact that several Cognitive Psychologists narrated the value of direct experiences.

Some models of teaching specifically tap on different intelligences. For example, cooperative learning emphasises interpersonal intelligence. The point in the new approach (MI Classroom) is that teachers should use a range of methods, materials and techniques to appeal to the multiple intelligences of learners. A few methods and materials that can be employed to profit from each Intelligence is listed below.

Intelligence	**Method/Materials**
Linguistics	Lecture
	Brain storming
	Discussion
	Story telling
	Reading in class
	Preparing class magazines
	Posters
	Books, tape-recorders

Logical - mathematical	Problem-solving
	Demonstration
	Puzzles and games
	Heuristic/explorative approaches
	Experiments, brain teasers, number games
Spatial	Charts, graphs, maps, photograph
	Slides, videos, movies
	Collage
	3D- Kits
	Computing, graphics
	Art materials, picture library
Bodily-kinesthetic	Field trips
	Mime
	Hands on activities
	Cooking, gardening
	Physical manipulations
	Body language,
	Signals to communicate
	Physical education activities
	Tools, clay, sports equipments
Musical	Singing, humming
	Using musical instruments
	Tape-recorder, musical instruments
Interpersonel	Cooperative learning
	Peer teaching
	Cross-age tutoring
	Group brain storming

	Community involvement
	Social gathering
Intrapersonal	Independent study
	Self-paced instruction
	Individual projects
	Programmed instruction
	Home work
	Materials for projects
Naturalistic	Aquariums
	Terrariums
	Gardening
	Nature videos
	Films and movies
	Binoculars, telescope, microscope
Existential	Readings in controversial issues, critiques on life and death issues, debates on controversial issues

Lesson Planning in MI Theory

Multiple intelligence (MI) theory suggests use of diverse teaching strategies and materials in teaching and learning processes. There is no definite guideline with respect to lesson planning. However, whatever is demanded by cognitive components of intelligence is to be satisfied. That is, during an academic year, lessons should be planned in such a way that all students can have their strongest intelligences addressed at least some of the time.

Armstrong (2001) suggested seven steps in creating MI lesson plan. The steps are - - (1) decide on the topic/objective, (2) relate the topic with nine intelligences, (3) consider the possibilities of using different techniques and materials appropriate for developing different intelligences, (4) brainstorm the various alternatives to generate a minimum of two ideas to address each intelligence, (5) select appropriate activities taking into account the infrastructure facilities of the school/classroom, number of students in the class and time available, (6) set up a sequential plan of action to address each intelligence and (7) implement the plan.

While trying to relate the topic with nine intelligences (step 2), several probing questions should be asked. For example, how can I use spoken or written words? (linguistic intelligence), how can I bring in logical thinking skills or classifications? (logical-mathematical intelligence), how can I use visual aids? (spatial intelligence), How can I bring in a rhythmic or melodic framework? (musical intelligence), How can I use hands-on experience? (bodily-kinesthetic intelligence), how can I engage students in peer sharing or cooperative learning? (interpersonal intelligence), How can I evoke personal feelings or give students choices? (intrapersonal intelligence), How can I relate the topic with natural phenomena or living things? (naturalistic intelligence) and How can I address current controversies (nuclear weapons) in science? (existential intelligence).

Classroom management techniques have been suggested by MI theorists (e.g., Armstrong, 2001). Some of the strategies for gaining students' attention are - - write the words "silence please!" on the black board (linguistic strategy), clap your hands rhythmically (musical strategy), put your finger against your lips to suggest silence (bodily-kinesthetic strategy), put up a picture of an attentive classroom on the board and refer to it with a pointer (spatial strategy), use a stop watch to notify (write on black board) the time being wasted (logical-mathematical strategy), whisper in the ear of a student, "It is time to start - pass it on" (interpersonal strategy), start teaching the lesson and allow students to take charge of their own behaviour (intrapersonal strategy) and play a recording of a sound of a bird or animal (naturalist-strategy). Most of the strategies are appropriate for primary and upper primary school students. However, similar strategies appropriate for high school and higher secondary school students are to be developed. In the new approach, the instructional objectives are stated as curriculum statement or curricular objectives. These statements include objectives and specific objectives. Specific objectives are measurable and observable change of behaviour. They are very concrete, definite and clear expressions of learner behaviours. Keeping in view the target objectives, teachers look for specifications. Each objective has its own specifications and they are written as action verb.

Format of an alternate lesson plan

1. **Preliminary details/General information**
2. **Content Overview**: (Broad outline of the content)
3. **Content Analysis**: (Analysis of the content area into terms, facts, concepts, definitions, principles etc.)
4. **Curricular Objectives**:
   Specific Objectives:
5. **Strategies**: Group activities, Discussion Strategies
6. **Pre- requisites**:
7. **Misconceptions** (identified/anticipated):
8. **Learning Materials**:
   A. **Glass wares/apparatus**
   B. **Chemicals/Consumables**
   C. **Improvised Apparatus/Charts/Models**
9. **Precautions/First aid**:
10. **Process/Activities** **Response/Evaluation**
    Orientation/organisation/introducation
    Number of groups to be formed
    and number of session
    Sessions No. 1 to 4 or 5 (duration)
11. **Follow-up Activities**
    (a) Written Assignment
    (b) Activity Assignments

Sample lesson plans both in chemistry and physics in two column format are given in Appendix IV and V.

Chapter IX

EVALUATION

Evaluation is an integral part of any process. The word evaluation goes beyond answering the question "how much?" To know how much we need only measurements, but evaluation is something more. Evaluation is the act or process of determining the value of something. Value judgement is possible only with the help of a standard or a frame of reference. In education, the frame of reference for evaluation is the objective without which there cannot be any evaluation. Thus evaluation is the process of determining how effectively students are advancing toward learning objectives (Thomas, 1960).

In education, evaluation helps to measure the progress of students and the teacher effectiveness. The Report of the Education Commission (1966) summarises the concept of evaluation in the following lines. "It is now agreed that evaluation is a continuous process, forms an integral part of the total system of education and is intimately related to educational objectives. It exercises a great influence on the pupil's study habits and the teacher's method of instruction and thus helps not only to measure educational achievement but also to improve it" (p. 243). Evaluation has the following three dimensions:

1. The measuring aspect of evaluation

To evaluate, the extent of change happened in the learner has to be measured. How much is the change? Is the student progressing in all the expected domains of development? Which domain needs more attention? This is one of functions of evaluation.

2. The classifying aspect of evaluation

The measurement indicated by the quantity, say marks obtained in an achievement test in Chemistry, is sufficient to promote the learner to the next higher level of learning.

3. The guidance aspect of evaluation

Evaluation serves to guide the teacher and the taught. Teacher can diagnose the difficulties of the pupil and suggest appropriate remedial measures. Teacher can look toward himself/herself in understanding common errors committed by students. In other words, the efficiency of the teacher can be assessed by evaluation.

There are different tools such as achievement test, questionnaire, interview, rating scales, etc., that will assist in the process of evaluation. Here, the discussion will be limited to achievement tests.

Achievement Tests

Achievement test measure the effects of learning that occurred under partially known and controlled conditions. A test of educational achievement is the one designed to measure different objectives in a specified subject or a group of subjects (Freeman, 1962). The written examination, Horace Mann noted, put all students in a uniform situation, permit a wider coverage of content, reduce the chance element in question choice, and eliminate the possibility of favouritism on the part of the examiner (cited in, Anastasi, 1968). The achievement tests usually have the following four objective type test items (Ahmann, 1965). They are - - (1) supply test items, (2) true-false test items, (3) multiple-choice test items and (4) matching test items. Each type is detailed below.

1. Supply-test Items

Supply test items are questions or incomplete statements which require highly abbreviated answers, which is a significant word or expression. An important advantage of supply test item is that the possibility of the students guessing the correct answer is reduced. Moreover, s/he must recall it rather than recognise the correct response. Strictly speaking, supply test item is not an objective test item as we cannot eliminate the subjective judgement of the students' response. Moreover, there is a possibility of the students' answer being partially correct.

2. True-false Test Items

True-false test items are difficult to construct as every generalisation has got exceptions. In order to construct cent percent correct or false statement, the teacher may have to add several adjectives which incorporate a number of ideas that may confuse the students.

3. Multiple-choice Test Items

Multiple-choice test items are composed of a stem followed by a series of possible responses or options. The distracters/options should be plausible, so that the pupils who do not possess the achievement being evaluated will tend to select them rather than the correct answer. The test maker can attain plausibility by making the distracters familiar, reasonable, natural and related to the same concept as the correct answer. (One method, though not easily accessible is to use a completion test item and then tabulate the incorrect responses of pupils and to include those responses which have high frequency as distracters). The stem is usually a direct question or incomplete statement. The options are usually four or five in number, only one of which is the correct answer. The incorrect responses are distracters or foils. This is the most popular test item in standardised tests. Multiple-choice test items include recall of information as well as complex student behaviour patterns such as to analyse and synthesise. Often, attempts are made to score wrong responses, which give a more intimate view of the students' command of the subject matter involved in the test item.

4. Matching Test Item

Matching test items consist of two, occasionally three, lists of items and a set of instructions for matching one of the items in the first list with one or more of the items in the second or third list. Every effort is made to keep the lists as homogeneous as possible. Students can respond to this type of objective test item quite rapidly, provided that the list of the responses is relatively short.

Ahmann (1965) has raised four major criticisms about objective test items. They are:

1. Objective test measures only factual knowledge
2. Objective test items are ambiguous particular to better students.
3. Objective tests encourage students to learn small bits of knowledge rather than broad understanding and discourage writing efforts.
4. Objective tests encourage the students to engage in guessing

The first criticism is not valid, as successful test items can be designed so as to measure students' comprehension and discrimination. Pre-testing and subsequent will do away with the second criticism. The third criticism can be minimised by including questions of higher objective, but it sis true that the writing efforts are discouraged. Since science curriculum does not emphasise on the objective of 'developing expression,' it cannot be considered as a limitation here. The problem of guessing is persistent but can be discouraged by negative scoring for the incorrect answers. To sum up, objective test items are unique in all respects except for the guessing and lack of expression.

Essay test items are helpful in measuring the development of expression, reasoning, explanation and advancing an argument. Most evaluation specialist today will agree that essay-objective test controversy is not an either or proposition. Most of the techniques when properly used can and should be valuable tools for the teacher to use in evaluating the much different behaviour which educational objectives define. However, there are several limitations to essay type items (Schwartz & Tiedman, 1957).

1. Essay tests are an inefficient method of measurement. Multiple-choice test is much more efficient than the essay test and permits a more comprehensive measurement. However, the criticism is valid if the content or topics involved are readily adaptable to objective testing.
2. Essay test cannot be reliably graded. The scores assigned to a

single paper by different teacher show a high range of variability.

3. Essay test encourage bluffing. The essay test, if loosely graded, does provide an opportunity for bluffing.
4. Grading of essay tests is too often influenced by extraneous factors such as spelling and hand writing. Critics of essay tests argue that grades on essays often reflect not only an evaluation of what was written but a conscious or unconscious bias resulting from errors in spelling, grammar, and from poor hand writing.

Construction and Administration of an Achievement Test

There are seven steps in the construction of an achievement test. They are:

1. Designing the test
2. Preparing the Blueprint
3. Preparation of Items
4. Editing of Question Paper
5. Administering the Test
6. Scoring the Test
7. Evaluating the Test

Each of the above steps is detailed below.

1. Designing the test

The first step in constructing an achievement test is to design the test. There are four dimensions to the design. They are - - (a) weightages to objectives, (b) weightages to content, (c) weightages to the types of questions, and (d) weightages to the difficulty level. Each of these designs is detailed below.

(a) Weightage to objectives

What objectives are to be tested and what weightages are to be given to different objectives will be stated in this design. Weightages to the different objectives are given according to the nature of the unit and also based on the importance given to different objectives during instruction. The relative importance should be considered in allotting weightages. The design should contain the list of objectives, the marks for each objective, percentage of marks, and the total marks for the achievement test.

Design No. 1

No.	Objectives	Marks	% of Marks
1	Knowledge & Understanding	15	60
2	Process Skills	5	20
3	Application	5	20
	Total	25	100

(b) Weightage to content

The content to be tested and weightages to be given to different areas of content are stated in this design. The content (unit/chapter) to be tested is divided into three or four subunits. The subunit which is important can be inferred from the time spent in teaching the subunits. By giving weigthage to each subunit, the test is made comprehensive (incorporating representative items from all content areas).

Design No. 2

No.	Objectives	Marks	% of Marks
1	Reaction rates	6	24
2	Chemical equilibrium	12	48
3	Calculation of reaction rates	7	28
	Total	25	100

(c) Weightage to the types of questions

Form of the question to be used and the weightages to different forms of questions are stated in this design. A test is meant to measure more than one objective, as such, different forms of questions suitable for the measurement should be included, keeping in view, the relative importance of the objectives to be tested. The weightages to be given to each form of question should be decided on the basis of the time needed for answering the items tested and the skills involved.

Design No. 3

No.	Objectives	Marks	% of Marks
1	Objective (O)	10	40
2	Short Answer (SA)	10	40
3	Essay	5	20
	Total	25	100

(c) Weightage to the difficulty level

The weightages to the difficulty level is given as per the spirit of the Normal Distribution Curve (NDC). A good test will have items of varying difficulty so that discrimination is possible among students. Majority of questions should be of average difficulty such that all students can attempt those questions. There should be some easy questions that all the students can answer. The remaining items should be difficult questions of high standard that only bright students can answer.

Design No. 4

No.	Objectives	Marks	% of Marks
1	Easy (E)	5	20
2	Average (A)	15	60
3	Difficult (D)	5	20
	Total	25	100

2. Preparing the blueprint

A blueprint gives the details of the designs in concrete terms. It is a three-dimensional chart giving the placement of different questions with respect to: (i) objectives tested, (ii) content areas covered, and (iii) the types of questions. In addition to these dimensions, the blueprint will also indicate the numerical weightage to each question individually. Format of the blueprint is given below.

Blue print

Standard: Subject:

Time: unit:

Total Marks:

	K & U			Process Skills			Application			Total
	O	SA	E	O	SA	E	O	SA	E	
I										
II	(10) 1				(11) 2					
III										
Subtotal										
Total										

N.B. Number inside the bracket indicates question number and the number outside bracket indicate the marks allotted.

3. Preparation of items

Multiple choice items should be drafted with utmost care. A few suggestions for constructing Multiple Choice items are given below.

General rules

1. The item as a whole should present a problem related to an identifiable objective of teaching
2. The item as a whole should be presented in a form which makes it easy for the pupil to understand the nature of the problem to be solved.
3. One item in a test should not provide information needed in solving another item in the test.
4. Grammatical consistency should be maintained throughout the item.

Rules for stating a problem/question

1. The stem may be in the form either of a direct question or an incomplete statement. If the incomplete statement form of stem is used, it should be meaningful in itself and imply a direct question.
2. The problem stated in the stem must have a definite answer.
3. The problem must be accurately stated and should not include irrelevant materials.
4. The problem/stem should be stated in a positive form.
5. The distracters of multiple-choice item should be plausible, so that the pupil who does not possess the achievement being evaluated will tend to select them rather than the correct answer.
6. The distracters should be as homogeneous as possible.
7. The suggested answers should be as brief as possible.
8. The number of distracters/decoys should be four or five.

Item card

It is desirable to prepare item cards in the process of compiling test items. An item card is a method of keeping track of the items prepared for the test. The item card is a 5" X 3" card on which information such as unit, sub-unit, objective, specification, item type, difficulty level, marks and estimated time are written on one side and the item is written on the other side. This will facilitate item choice and sequencing of items as per the estimated item difficulty

Facing side (side 1)

Unit	Energy changes	Sub-unit	Endothermic
Objective	Knowledge	Specification	Recognises
Item type	Objective (MC)	Difficulty level	Average
Marks: 1		Time: ½ a minute	

The other side (Side 2)

Water gas is a mixture of …………………
A. Carbon monoxide and hydrogen
B. Oxygen and hydrogen
C. Carbon monoxide and oxygen
D. Carbon dioxide and hydrogen

4. Editing of question paper

Scheme of options and sections

In preparing a test, the scheme of option and scheme of section are to be decided in advance. The practice of providing option is not considered to be sound and should be avoided. Whenever options are given, internal option is preferred to overall option. Internal option will discourage selective study. The options given should be similar in form, content, objective and difficulty level. The question paper is usually arranged in sections depending on the type of questions included in the test. The objective type questions are very often given in a separate sheet and collected back at the end of the time limit.

Editing of question paper is of crucial importance. It consists of - - (1) assembling the questions, (2) instructions to examinees, and (3) total marks and total time. Each aspect is discussed below:

(1) The questions should be arranged into different sections on the basis of types of questions. They should be arranged in the increasing order of difficulty. The gradation in difficulty will help the students in answering the questions so that the student is not held up by a difficult item while comparatively easy items are waiting to be attempted.

(2) The paper setter should take care in giving direction to the examinees with regard to what they are supposed to do with respect to each question. These instructions should be specific and unambiguous. General instructions, if any, should be given at the beginning of the question paper and specific instructions

related to a particular section should be given just before the beginning of the section.

(3) Total marks and total time allotted for the whole question paper should be given at the beginning. Marks for each question or for each section may also be given at the right-hand side of the margin.

5. Administering the test

The editing may have important implications for the administration of the test, viz., collection of answer script for the section containing objective type questions. Such implications should be anticipated and necessary arrangements should be made and proper direction should be given well in advance.

6. Scoring the test

Scoring key should be prepared for objective type items. If the objective type item is multiple-choice, the key may be prepared as follows.

Qn. No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Key	**A**	**D**	**C**	**A**	**B**	**A**	**C**	**D**	**B**	**A**

Marking scheme should be prepared for Short Answer and Essay questions. The marking scheme gives expected outlines of the answer and marks for each point or aspect of the questions. The relevant points should be mentioned briefly so as to maintain objectivity in the process of evaluation. A sample question and relevant value points are given below.

Question: With the help of a diagram describe the preparation of Sulphur Dioxide in the laboratory.

Qn. No.	**Value Points**	**Marks**	**Total**
..	Chemical equation of the reaction	2	
	Diagram	1	
	Labelling	1	5
	Neatness	$^1/_2$	
	Proportionality of figures in diagram	$^1/_2$	

7. Preparation of Question-wise analysis

The question paper is analysed in terms of sub-unit, objectives, and specifications, type of questions, marks, estimated difficulty and estimated time. This analysis is very helpful to check the question paper against the blue-print. A proforma for the question-wise analysis is given below.

Qn. No.	**Sub-unit**	**Objective**	**Specification**	**Type of question**	**Marks**	**Estimated difficulty**	**Estimated time**
..	Pyrotechny	Knowledge	Recognises	Objective	1	Average	½ a minute

8. Evaluating the test

Evaluation of a teacher made test is detailed below under the title 'standardised test'.

Standardised Test

One meaning of the word 'standardised' is that specific and detailed directions for test administration and scoring procedures are established. "A standardised test is a test which comprises of carefully selected items, having been given to a number of samples or groups under standard conditions and for which norms have been established after careful evaluation" (Bhatia, 1973, p. 104). The development of a standardised test requires a pre-test followed by an item analysis to help identify those items which might be unsatisfactory. Supplementary materials include manuals that explain the purpose and use of the test and reports of technical information on its reliability, validity and other characteristics. Thus, a standardised test is presumably one that has been prepared with care by specialists, tried out experimentally and then published. Norms are ordinarily supplied so that a student's score can be compared with those of defined group of students, often a nation-wide sample.

Three important merits of a standardised test are - - (1) A standardised test is accompanied by carefully established norms for comparing achievement of pupils of the same age and grade, (2) Standardised tests are carefully designed keeping in view the instructional objectives and they possess greater objectivity, and (3) Standardised test is superior in validity, reliability and other technical aspects since try-out and evaluation are made (Bhatia, 1973). Ahmann (1965) prescribed five steps in the construction of standardised tests. They are:

(1) Planning

(2) Writing the test item

(3) Pre-testing

(4) Analysing

(5) Norming

(1) Planning

The primary concern in planning is to identify specifically what goals the test should accomplish. In case of achievement test, the specifications (by the representatives) are outlined in considerable detail. The subject matter to be covered, the types of behavioural changes of the students to be sampled is carefully cross referenced by means of tables of specifications.

(2) Writing the test items

The test items should evaluate only the stated objectives. The item should give maximum weightage to most important objective.

The test item should be so organised that the student understands the question asked or the problem to be solved. The type of answer desired should be understandable to the student who knows the material.

(3) Pre-testing

The pilot-test or try out form of the test is called a pre-test. The pre-test consists of a larger number of items (usually three times of the number of required items) than the final test.

(4) Analysing

The individual test items are analysed to assess the Difficulty Index or level (DI) and Discriminating Power (DP). On the basis of the analysis, items are selected and a final form of the test is assembled.

Item Difficulty

Test item difficulty index is the percentage of students who answer a given item correctly. The following formula is used to determine the item difficulty or Difficulty Index (DI)

$$DI = \frac{U+L}{2N} X100$$

Where U and L are number of right answers in the Upper and Lower Groups and N the number of students in each group, or

DI =

Where N_r is the number of students who answered the test item correctly and N_t the total number of students who attempted the test item.

The calculated percentages range from 0 to 100. It is most desirable that the percentages cluster around the 50 percent level. In case of well developed test the range is between 30 and 70. The knowledge of DI helps to arrange the items in the increasing order of difficulty so that the student is not held up by a difficult item while comparatively easy items are waiting to be attempted.

Discriminating Power

Test item discriminating power is the capability of the item to differentiate between superior and inferior students. A small segment of the high scores and a small segment of low scores are used to identify the upper group and the lower group. The size of the Upper Group and Lower Group can vary, but it is generally taken as 27% of the total group (Kelly, 1939). The general equation for calculating DP is given below.

$$DP = \frac{U - L}{N}$$

Where U, is the number of students who answered the item correctly in the Upper Group; and L, number of students who answered the item correctly in the Lower Group, and N, number of students in each group.

Kelly (1939) had suggested the Upper and Lower group as the 27% for the ease of calculation. For example, suppose there are 1000 students who attempted all the items in a test. 370 answer scripts of students can be randomly selected. These 370 answer scripts should be arranged in the ascending order of their total score. Of the 370, 27% of the lowest scores will constitute the Lower Group and 27% of the highest scores will constitute the Upper Group. The 27% of 370 is approximately 100. Thus the denominator in the equation is 100. Thus the calculation is made easy.

(5) Norming

A norm as the term used in relation to test scores, is the average or typical test score for the member of a specific group (Ebel, 1966, p. 455). The raw score is converted to some relative measure for easy interpretation. Norm indicates the individual's relative position in a normative sample and permits an evaluation of his/her performance in reference to other persons (Anastasi, 1968, p. 67). Moreover, a direct comparison of the individual's performance on different tests is possible. Of the different norms, percentile rank is the most widely used.

In the process of developing norms, the test is administered to a sample of students typical of those for whom the test is originally designed. The scores of the students are classified into reasonably homogeneous groups according to pertinent student characteristics such as age, Socio Economic Status (SES), type of school, and geographic area. The test results are arranged in tables in such a way as to provide a basis for comparison between the test score of a student and the typical performance made by the sample of the students.

Qualities of a good measuring tool

Apart from being objective-based, comprehensive, possessing the qualities of objectivity and power of discrimination, a test should be valid and reliable. The concept of validity and reliability will detailed below.

Validity of a test

The concept of test validity pertains to "what the test measures and how well it does so" (Deighton, 1971, p. 393). Validity has to do with the meaning of the score assigned and the inference from that score on that indicator to the construct the researcher intended to measure. An index of validity shows "the degree to which a test measures what it purports to measure, when compared with an accepted criterion" (Freeman, 1962, p. 88). "Validity is the correspondence between the construct and the indicator and the ability of measurement procedure to yield scores that represent the true amount of the indicator possessed by each individual" (Smith & Glass, 1987, p. 111). No indicator attains this ideal; the idea that there is even a "true amount" is disputed by some. Validation is the process of studying the accuracy of predictions and inferences made from test scores. Strictly speaking one does not validate a test; rather one evaluates a certain kind of interpretation of data derived from a specified procedure. A particular test is published for users who have many different purposes. Each user requires a different interpretation and each interpretation has its own degree of validity. Hence there is no such thing as "the validity" of a test. No test is valid for all purposes, in all situations, or for all groups of students. There are five different types of validity - - (1) content validity, (2) face validity, (3) construct validity, (4) empirical validity, and (5) predictive validity. They are discussed below.

1. Content validity

Content validity involves the systematic examination of the test content to determine whether it covers a representative sample of the behaviour domain to be measured. The behaviour domain tested must be systematically analysed to make sure that all major aspects are covered by the test items, and in the correct proportions. Content must therefore be broadly defined to include major objectives of the domain. In other words validity refers to the degree to which content is measured accurately that reflects the concept it is intended to measure (Bohrrnstedt & Knoke, 1988). For example, an achievement test must contain items that represent the curriculum and the instructional objectives. Then only the data can be interpreted as a true indication of whether the instructional programme has been effective or not.

2. Face validity

Face validity is not validity in the technical sense; it refers, not to what the test actually measures, but what it appears to measure superficially. Fundamentally, the question of the face validity concerns with rapport and public relation. Is there logical consistency between the content of the test items (observation schedule, rating scale) and the definition of the construct? If the content appears irrelevant, inappropriate, silly or childish the result will be poor co-operation regardless of actual validity of the test.

3. Construct validity

The construct validity of a test is the extent to which the test may be said to measure a theoretical construct or trait. "Construct validity depends upon the degree to which the test items individually and collectively sample the range or class of activities or traits, as defined by the mental process or the personality trait being tested" (Freeman, 1962, p. 94). Construct validity of a given test might be demonstrated by calculating substantial correlation with other tests that have been shown to measure satisfactorily the mental process or traits in question.

4. Empirical validity

Empirical validity refers to the relation between test scores and a criterion, the latter being an independent and direct measure of that which the test is designed to measure.

5. Predictive validity

The term predictive validity has been used to describe validity coefficients between the indicator and some criterion assessed later in time. Predictive validity of a test is "the extent to which the test is efficient in forecasting and differentiating behaviour or performance in a specified area under actual working and living conditions" (Freeman, 1962, p. 89). For example, a measure of academic potential can be administered to a sample of high school pupils and correlated with the first-semester college grades for the same sample. A positive correlation provides some meaning to the scores on the academic potential test. Whatever construct it measures, it at least predicts college grades with some accuracy.

Reliability of a test

Test reliability refers to "the consistency of scores obtained by the same person when retested on different occasions or with an equivalent form of the test" (Deighton, 1971, p. 393). The concept of reliability underlies the computation of the 'error of measurement' of a single score, whereby we can predict the range of fluctuation likely to occur in a single individual's scores as a result of irrelevant chance factors (Anastasi, 1968). The test reliability indicates the extent to which individual differences in test scores are attributable to 'true' differences in the characteristics under consideration and the extent to which they are attributable to chance factors. In other words, reliability refers to the degree to which observations of a study are repeatable (Bohrrnstedt & Knoke, 1988). A measuring instrument is said to be reliable according to the degree to which it generates consistent observations at two points in time. Or a measure is reliable to the degree that two different researchers using the same instrument on the same sample would generate the same observations. Before any standardised test is released for operational use, its reliability must be empirically ascertained. A high reliability coefficient indicates that a student's score was not influenced much by the chance in selecting of certain items rather than some other items for inclusion in the test or by the students' luck or lack of luck in guessing the correct answer (Ebel, 1966).

Reliability can be checked with regard to score fluctuations over time, over item samples, or over examiners and other factors. Reliability of the same test may differ in different aspects and therefore, the type of reliability and the method employed to measure it must be specified in the test manual. The number and major characteristics of the persons on whom reliability was calculated should also be reported. With this information the test user can predict whether the test will be about equally reliable for the persons with whom she/he plans to use it or whether it is likely to be more reliable or less reliable. It must be noted that a measure of a concept cannot be valid if it is unreliable. However, a measure can be reliable (or consistent) without being valid (or a true measure). The test reliability is expressed mathematically in terms of variance of errors of measurement and reliability coefficients (Deighton, 1971). There are three methods which are widely used to calculate reliability - - (1) test-retest reliability, (2) alternate form reliability, and (3) split-half reliability. They are described below.

(1) Test-retest reliability

The most obvious method for finding out the reliability of test scores is by repeating the identical test on a second occasion. Test-retest reliability is the name given to this technique. It involves computing the correlation between the two sets of scores generated by repeated administration of the test. Reliability coefficients range from r = 1 (indicating perfect reliability) and r = 0.00 (indicting that all the variance in the measurement procedure is due to error). The higher the correlation coefficient, the greater the reliability and lower the amount of error that can be attributed to the temporary characteristics of the subjects. Test-retest reliability shows the extent to which scores of a test can be generalised over different occasions. When test-retest reliability is reported in a test manual, the interval over which it has measured should always be specified, since the correlation decrease progressively as the interval lengthens (Anastasi, 1968).

(2) Alternate forms reliability

Another way of addressing the reliability is to build parallel test or test forms and administer them to the same sample of subjects. This provides a measure of alternate forms reliability. The correlation coefficient between the two sets of scores is a measure of item equivalence. High values of the correlation indicate that the scores on individuals can be generalised beyond the particular items on that test to a population of similar items. Low correlations demonstrate how much an individual's scores are influenced by an item or two on one or the other of the test forms (Smith & Glass, 1987).

(3) Split-half reliability

It is possible to arrive at a measure of reliability from a single administration of the test. This procedure is an estimate of the internal consistency of a test. This procedure is known as split-half reliability, wherein the researcher divides the items in the test into two parts (such as the odd-numbered items and the even-numbered items), scores the two parts separately, calculates the coefficient of correlation between the two parts. The result indicates whether the two sets of items are measuring the same thing. It should be noted that the items on the test should be arranged in the approximate order of difficulty which yields very nearly equivalent half scores. The correlation coefficient calculated in this method provides reliability of only a half test. The reliability of the whole test can be calculated using the formula,

R =

Where R is the reliability of the whole test and *r* the reliability coefficient of the half test

Coefficient of correlation – Spearman's rank order correlation

Correlation provides us a measure of how two random variables are associated in a sample. If the relationship between two variables is such that larger values of one variable tend to associate with larger values of another, the correlation is said to be positive. A coefficient of + 1.00 denotes a perfect positive correlation. The value of correlation coefficient indicates the strength of association between the two variables. This means that when coefficient of correlation is close to +1, an individual with a high value for one variable will likely to have a high value for the other variable. For example, taller person weigh heavier. That is, there is a positive correlation between height and weight. But if larger values of one variable tend to associate with smaller values of the others correlation is said to be negative. A value of –1.00 denotes perfect negative correlation. (e.g., distances from the ground of persons X and Y while on a seesaw).

By correlation or association we mean the lack of statistical independence between variables X and Y. The lack of association means that the value of one variable cannot be reasonably anticipated by knowing the values o the other variable.

Correlation does not mean causation. For example, older women bear intelligent children. Correlation only means association. One variable may or may not be the cause of the others variable. A correlation coefficient is an index which shows the relationship between two variables.

A coefficient of rank correlation is calculated using the Spearman's rank order formula Rho (ρ).

$$\rho = 1 - \frac{6\sum D_2}{N(N_2 - 1)}$$

Spearman's coefficient of rank correlation is a statistic defined in such a way as to take a value of +1 when the paired ranks are in the same order and a value of –1 when the ranks are in an inverse order.

Continuous and Comprehensive Evaluation

Evaluation is a systematic process of collecting, analysing and interpreting evidences of students' progress and achievement. The term Continuous and Comprehensive Evaluation (CCE) suggests continuous assessment of the total growth and development of pupils. Continuous evaluation means that evaluation is conducted more frequently spread through out the total span of instructional time. Comprehensive evaluation refers to the evaluation of the total growth and development of the pupil – physical, mental, social, emotional and spiritual. Pupils are evaluated in both the scholastic and co-scholastic areas in respect of different aspects of development. CCE helps to evaluate those objectives of learning which cannot be evaluated through year-end written examinations. CCE has the advantage that situations are provided to make the evaluation much more comprehensive than possible by testing with a minimum sample of contents and objectives as done in terminal examinations.

In CCE, both the process and product of learning are evaluated. Therefore, tools to evaluate the process objectives should also be developed and used as part of teaching-learning strategy. The process objectives include observational and enquiry skills, collecting and recording data, appreciation of art and culture, cooperation, and development of values. To evaluate these objectives, a variety of evaluation tools such as observation schedule, anecdotal record, checklist, rating scale, etc. are used.

Components of evaluation

In order to flourish continuous and comprehensive evaluation we make use of the following components of evaluation.

1. Continuous Evaluation (CE)
2. Terminal Evaluation (CE)

I. Continuous Evaluation (CE)

In the activity-based classroom, teacher provides variety of experiences through varied tools such as brain storming, group work, discussion, project, seminar, debate, field visit, practical work, etc.

Taking into account the nature of the subject, several tools are advised for continuous evaluation. The common items used for CCE are - - (1) project, (2) field study, (3) seminar, (4) debate, (5) practical, (6) class test, (7) assignment, and (8) model preparation. The above items can be classified into five categories (SCERT, 2005).

Sl. No.	Area	Items
1.	Investigative activities	Project, Field study
2.	Interactive activities	Seminar, Debate
3.	Practical based activities	Practical
4.	Performance based activities	Class test
5.	Assigned tasks	Assignment, Model preparation

Evaluation of CE items

The CE items are to be evaluated on the basis of specific indicators or attributes given below.

1. Project

Structure of a project report

i. Title

Title of the project, name and address of the group members, year, etc. can be written on the cover page. In the first page, title of the project (a brief account of the topic to be studied), number of group members, name of the teacher, etc. can be written in an orderly manner. In the second page certificate by the guide about the project should be given. In the third page content of the project should be written briefly.

ii. Introduction

Introduction can be written, starting from fourth page.

iii. Objectives and or hypotheses

iv. Method and tools used for the study

v. Collection of data

vi. Analysis and conclusion

vii. Suggestions (if any)

viii. Reference

ix. Appendices (questionnaire, observation format, checklist, etc.)

The project diary is helpful to prepare project report. The learner should note down the objectives/hypotheses, methodology, duration of study, etc. of the project. The authenticity of the report and the genuineness of the data are verified using the project diary. Hence, it is desirable that the teacher may give instructions to prepare the project diary. The teacher may conduct interim evaluation to see whether the learner makes entries in the diary at the appropriate time.

Criteria of evaluation/specific indicators or attributes of a project

i. Planning skills score 4/3/2/1

a) Ability to determine the appropriate learning strategy

b) Ability to develop appropriate tools for the study

c) Ability to determine in advance the duration of study, details of activities to be done at each stage.

The ability for planning has to be assessed at the time of planning itself. Details of planning should be recorded in the project diary by the learner.

ii. Ability to collect data score 4/3/2/1

a) Ability to collect relevant data according to the plan

b) Ability to classify and arrange the data so as to help easy analysis

c) Credibility/reliability of the data can be verified from on the spot recordings in the project diary.

The pupils should get a clear idea about the sources from where data are to be collected. For example, the pupil should get help to find out the reference for a particular project. The teacher should conduct discussions with pupils to find out the feasibility of the project.

iii. Ability to analyse and arrive at conclusions
score 4/3/2/1

a) Ability to analyse data

b) Ability to arrive at conclusion on the basis of analysis

c) Ability to formulate suitable suggestions/proposals on the basis of findings

There may be projects where data collection is done as a group activity or individual activity. But, students should be encouraged to analyse and draw conclusions individually.

iv. Excellence of the project report score 4/3/2/1

a) Ability to prepare project so as to reflect procedure of the project

b) Quality of the report in communicating the findings.

c) Authenticity of the report

d) Consistency with the project diary

Evaluation of the learner should be done at each and every stage of the project. After evaluation, the reports may be returned to the learners.

v. Awareness of the content and methodology
score 4/3/2/1

a) Ability to substantiate conclusions

b) Ability to communicate/explain the methodology and strategies

Evaluation can be done during presentation of reports (for those who get opportunity for presentation). For others, short interviews may be conducted.

2. Field study

Criteria of evaluation/specific indicators/attributes of field study is given below

Sl. No.	Components	Score
1.	Planning	4/3/2/1
2.	Data collection	4/3/2/1
3.	Observation and involvement	4/3/2/1
4.	Preparation of report	4/3/2/1
5.	Awareness of the content	4/3/2/1

3. Seminar

Criteria of evaluation/specific indicators/attributes of a seminar is given below

Sl. No.	Components	Score
1.	Ability to plan and organise	4/3/2/1
2.	Ability for data collection	4/3/2/1
3.	Awareness of the contents (presentation of papers, participation in discussion, ability to establish ideas logically in discussion)	4/3/2/1
4.	Ability to prepare paper, (evaluation of observation/ clarity, arrangement of ideas)	4/3/2/1
5.	Excellence in presentation	4/3/2/1

4. Debate

Criteria of evaluation/specific indicators or attributes of a debate is given below

Sl. No.	Components	Score
1.	Participation at different stages	4/3/2/1
2.	Democratic approach	4/3/2/1
3.	Relevance and logic of the facts and concepts presented	4/3/2/1
4.	Communicative skill	4/3/2/1
5.	Preparation of report	4/3/2/1

5. Practical

Criteria of evaluation/specific indicators or attributes of practical is given below

Sl. No.	Components	Score
1.	Systematic procedures (understanding about scientific principles, order of working etc.)	4/3/2/1
2.	Skills to handle tools	4/3/2/1
3.	Accuracy/precision in the activities (controlling variables, measurement, recording, display)	4/3/2/1
4.	Analysis of data	4/3/2/1
5.	Excellence of the record	4/3/2/1

6. Assignment

Criteria of evaluation/specific indicators or attributes of assignment is given below

Sl. No.	Components	Score
1.	Awareness of the content	4/3/2/1
2.	Comprehensiveness of the content	4/3/2/1
3.	Excellence in creativity (clarity and suitability of structure); excellence in language (for language assignment); systematic analysis	4/3/2/1
4.	One's own observations, evaluations, etc	4/3/2/1
5.	Time-bound completion	4/3/2/1

7. Model preparation

Criteria of evaluation/specific indicators or attributes of model is given below

Sl. No.	Components	Score
1.	Relevance	4/3/2/1
2.	Improvisation skill	4/3/2/1
3.	Creativity	4/3/2/1
4.	Preparation of report	4/3/2/1
5.	Awareness of the content	4/3/2/1

II. Terminal Evaluation (T.E)

Terminal Evaluation should be in written form. The intention of the test must not be confined to testing of memory. It is an important tool for evaluating the facts, concepts, ideas gained by the learner. While preparing questions for the terminal evaluation, more emphasis should be given to the level of application, analysis, synthesis and evaluation than knowledge and understanding.

Grading

In evaluation, we make use of two systems such as marking system and grading system for assessing the performance of the learner. Consider an achievement test of total score 100. There is a possibility of getting zero score to 100 score for individuals. In other words, we can say that this is a 101 point scale. It is very difficult to distinguish a learner scored 89 with another learner who scored 90. There may not be any measurable difference in the abilities of these two learners using the test-items. To overcome such limitations a popular mode of evaluating students' performance known as grading system has been evolved. It is used all over the world. The common types of grading used are absolute grading and relative grading. In absolute grading scores are given for the evaluation items. Then they are converted into percentage and appropriate letter grades corresponding to each score. This is also referred to as criterion referenced grading. In relative grading the grade assigned to a student is based on his/her level of performance with respect to others.

Assessment of Skills, Interests and Attitudes in Science

Assessment or evaluation is a continuous enterprise, which is an integral part of teaching-learning process. By using various assessment procedures, teacher may get a clear idea about the extent of development of his/her students in different dimensions. Thus, the teacher will be able to know the appropriateness of the learning strategies adopted, and to organize adequate learning tasks for students. Hence, the assessment processes become beneficial for both the teacher and the students. Here the procedures for assessment of skills, interests and attitudes in science are discussed.

1. Assessment of Skills

A skill can be defined as the ability to perform a task with expertise, mastery and efficiency. A number of skills is essential in the learning of science since it involves a great deal of experimentation. Science learning aims at the development of psychomotor skills such as manipulating skill, drawing skill and observational skill. To assess these scientific skills following procedures may be used.

a) Practical tests – Observation of actual performance

Practical test is essential, when it is intended to test manipulative skills (Joseph, 1982). Here the assessment is carried out by the observation of actual performance of the learner. In practical examinations students are allowed to design an experiment to prove a principle, plan the entire procedure, handle materials and apparatus, perform the experiment and observe the results from which inferences are drawn. The observation of such practical examination enables the teacher to rate the student in terms of his/her proficiency in scientific skills.

b) Evaluation of records

Evaluation of students' records of observation helps the teacher in assessing the observational skill of students. The record works also give an idea about the students' skill in drawing, provided such instances are included in it.

c) Written tests

Generally, it is not possible to assess the performance or skills using written tests. However, some skill-related outcomes can be tapped through writing. Using written tests, it is possible to assess mastery of some of the complex knowledge that is prerequisites to perform the skill in question (Stiggins, 1997).

For example if a student doesn't know how the functions of different pieces of science lab equipment relate to one another in an experimental context, there is no way that student will successfully complete the lab work. The teacher could devise a question in the written test to see if he/she had mastered the prerequisite knowledge. The assessment of drawing skills can also be carried out using written examinations.

2. Assessment of Interests

An interest may be defined as "a tendency to seek out an activity or object, or a tendency to choose it rather than some alternative" (Cronbach, 1969, p. 339). Every individual has preferences for some activities or objects and aversion to others. These preferences emanate from the underlying interests of that individual. Interests propel a person to do his/her best in the work assigned to him/her. Interests of an individual are not of equal strength. They may vary in strength and potency. The following procedures are widely used to assess the interests including scientific interest.

a) Use of interest inventories

Interest inventories are 'self-reporting' devices, generally in the form of questionnaires. Items may be given in these inventories as questions for which the student has to give responses, or as incomplete sentences, which are to be completed by the student. In such inventories, the teacher could inquire about students' hobbies, what they do in their leisure time, and what types of books they read or show they watch. From the responses of student to these items, the interest of the student can be assessed.

In order to measure interest the popular tools used are the **Strong Vocational Interest Blank** and the **Kuder Preference Record**. The Strong Vocational Interest Blank has 400 questions or statements regarding specific areas, and the respondent is expected to mark his preference (Like, Indifferent or Dislike) to each item. In the Kuder Interest Inventory, a respondent has to choose one activity from the three activities mentioned in each group. Special answer keys are provided to score the responses. The scores obtained by an individual enable one to get an adequate knowledge of his/her interest.

For a science interest inventory, the items included will be designed to measure the individual's interest in the field of science. Example: Kerala University Science Interest Inventory (Nair & Thomas, 1971). Some illustrative items from this inventory are given below.

The respondents are asked to indicate one of the activities they like most from the given set of three activities for each item.

1. A - Listening to political speeches

   B - Attending science lectures

   C - Listening to religious discourses

2. A - Seeing movies
   B - Visiting factories
   C - Attending cultural programmes
3. A - Join the N C C
   B - Join a Science Cub
   C - Join a Social Service League
4. A - Make an electromagnet
   B - Make wooden models
   C - Make clay models
5. A - Reading newspapers
   B - Reading books on spiritual subjects
   C - Reading popular science magazines

b) Teacher observation and record keeping

As an alternative to asking students about their interests through inventories, a teacher can observe the students' activities and keep a record of these observations. To record various activities of students the teacher can use audio/video recording devices also. These recordings may provide valuable information regarding the interest of students. The leisure time activities of students may provide hints to the teacher about their interests.

An overview of science interest of children can also be ascertained from their selection of reading materials. By keeping a record of these reading materials, a teacher can see if children increase their voluntary selections of science books, which indicate science interest.

3. Assessment of Attitude

An attitude is an emotionally toned pre-disposition to react in a certain way towards a person, an object, an idea or a situation. Allport defined attitudes as a "mental and neural state of readiness, organised through experience, exerting a directive or dynamic influence upon the individual's response to all objects with which it is related" (cited in Skinner, 1995, p.326). Attitudes can be stated as likes and dislikes of a person, which are based on experience that affect later behaviour. The personal likes and dislikes are influenced by interests and values.

Scientific attitude is one of the outcomes of science teaching. It is characterised by - - (1) critical observation (2) open-mindedness (3) curiosity to know more about things around one (4) disbelief in superstitions and (5) objectivity in one's approach to problems.

Scientific attitude can be assessed using techniques like teacher observation and anecdotal records, recordings, rating scales, interviews, children's work products, situation evaluation, etc. (Yadav, 1992). Some of the methods used for the assessment of scientific attitudes are discussed here.

a) Teacher observation

The teacher may observe and record anecdotes of student's scientific or unscientific behaviour. From these records, the extent of scientific attitude of students can be estimated.

b) Recordings

Use of audio/video recording during science discussion can be used for assessing the scientific attitude. The conclusions arrived from these recordings will be more objective than that of written recordings.

c) Interviews

Personal interviews of individual or small groups of students enable the teacher to probe into their scientific attitude.

d) Using attitude scales

Two widely used measuring devices - - **Thurstone's scale of equal appearing intervals** and **Likert's scale of summated ratings** can be employed to assess attitude towards science.

(i) The method of equal appearing intervals.

This method was originally devised by Thurstone and Chave in 1929 and has been modified subsequently (Edwards, 1957).

Procedure

A number of statements related to the psychological object (in the present context, science) are collected and given to judges (say 100 in number) who are asked to classify them in an eleven point scale, showing each statement's degree of favourableness towards the psychological object. Through this rating procedure, the number of judges placed each statement at different points (1 to 11) is found out. From this the median or scale value for each statement is calculated. The items for the final scale are selected based on the variance and scale values. That is the items should have less variance (high level of agreement among judges regarding the position of statement) and they should be fairly and evenly spread on the scale continuum. Such statements (say 25 to 35 in number) which are relevant and least ambiguous are arranged in a random order to form the final scale.

The respondents are asked to indicate the statements with which they agree. The total scale values of those statements will give the attitude of the respondent quantified.

(ii) The Method of summated ratings

Likert introduced this method in 1932; it is simpler, easier and less laborious than that developed by Thurstone.

Procedure

A large number of statements which express a feeling (favourable or unfavourable) towards the psychological object are collected. The statements are scrutinised to avoid ambiguous or irrelevant items. The draft scale containing approximately equal numbers of favourable and unfavourable statements are administered to a sample (say 200) of the same population for which the scale has to be constructed. Each item or statement is followed by five responses indicating degree of strength of attitude – Strongly Agree (SA), Agree (A), Undecided/ Uncertain (U), Disagree (D), and Strongly Disagree (SD). The respondents are asked to indicate any one of them for each item. The responses Strongly Agree (SA), Agree (A), Undecided/Uncertain (U), Disagree (D), and Strongly Disagree (SD) are given scores 5,4,3,2 and

1 if it is a favourable statement and 1,2,3,4, and 5 if it is an unfavourable statement.

Based on total scores, 27 percent of the subjects with high scores and 27 percent of the subjects with low scores are taken as criterion groups. Selecting criterion groups of twenty seven percentage provides the best compromise between two desirable but inconsistent aims - - (1) to make the extreme groups as large as possible, and (2) to make the extreme groups as different from one another as possible (Ebel & Frisbie, 1991, p. 227). From the mean scores of items, calculated for each of the criterion groups, 't' value for each statement is found out. Then 20 to 25 items with high t values ($t > 1.75$) are selected for the final attitude scale, with approximately equal numbers of favourable and unfavourable statement.

The final scale can be administered to the population and the scoring procedure is same as that for draft scale. If the number of statement is 25, then a score $25 \times 3 = 75$ corresponds to a neutral attitude, while less than this value indicates unfavourableness and more than that indicates favourableness (Best & Kahn, 2005).

Chapter X

CO-CURRICULAR ACTIVITIES

The learning activities carried out inside or outside the school premises, which supplement the classroom learning, are generally termed as co-curricular activities. They help in developing scientific attitudes, interests, skills and values in students. The inspiring and encouraging experiences students gain through these activities may foster the 'scientists' in students. The common co-curricular activities, which are feasible in our schools, are discussed here.

1. Field Trips and Study Tours

Field trip or study tour to places of scientific importance plays a major role in the process of learning science. A field trip is a planned visit to a place outside the regular classroom. Through field trips, students see other people doing work in the natural setting. Field trips motivate pupils to learn science and stimulate their interests. A science teacher can utilise community resources through field trips. They supplement, enrich and correlate classroom teaching. The advantages of field trips and study tours as enumerated by Joseph (1982) are:

i. Motivate children to learn science.

ii. Get opportunity to have first-hand experience.

iii. Supplement classroom instruction.

iv. Provide opportunity to see things in their natural form.

v. Provide opportunity to collect specimens and other useful material.

vi. Stimulate spirit of collective working and sociability.

vii. Help in the assessment of the importance of science.

viii. Foster scientific enquiry.

The first-hand experience, they provide tends to be more meaningful and they arouse interest in students than the classroom/ laboratory experiments and demonstrations. Some useful field trips are:

1. Visits to chemical and other industrial plants such as sugar mill, tea factory, oil refinery, soap factory, ceramic factory, glass factory, etc.,
2. Power generating stations,
3. Airports and sea ports, and
4. Water and sewage works.

Distinction between Field Trip and Study Tour

Study tours are considered broader in scope than filed trips. While field trips are mainly intended to supplement classroom learning, study tours aim at developing social skills and values also. Field trips may be arranged with a specific purpose that is to gain direct experience of a principle, which is learned in the classroom. For example, to understand the process of purification of water, the teacher may plan a visit to near by water purification plant. In study tours, which may last for more than a day, the students get direct experiences from the places they visited as well as they learn 'how to live with others.'

Organisation of Field Trips and Study Tours

Educational field trips need careful and detailed planning; Sharma and Sharma (1971) suggested five steps in the conduct of field trips. They are: (1) Planning, (2) Preparation, (3) Execution, (4) Follow-up, and (5) Evaluation. Each step is briefly discussed below.

1. Planning

The concerned teacher should survey the proposed site for field trip. The teacher should discuss the plan with students who will be participating in the field trip. The date and time should be decided in advance. The transport and other travel arrangements should be made at least a month in advance. The anticipated expense per student should be calculated based on the total expense for transport, food, lodging and other expenses.

2. Preparation

The purpose of the visit should be made clear to students. The places of interest should be detailed as a part of preparation. Small groups should be formed to take responsibilities that will need students' participation. Permission of the owner or person-in-charge of the place to be visited should be secured well in advance. Written permission from parents should be obtained before the commencement of the programme.

3. Execution

Execution stage will be easier if the planning and preparation were adequate. However, unanticipated things may happen during a field trip. It is desirable to keep contact telephone numbers of school personnel to inform any such events. During the execution, the teacher should act as a supervisor.

4. Follow-up

Follow-up is important after any educational field trip. Students may be asked to write a report of the field trip, to make a model or to display the collected materials. The teacher can encourage them to write an essay for the school magazine based on the field trip.

5. Evaluation

Evaluation of the field trip acts as a guide for the teacher to improve his/her role in the conduct of the field trip. The most enjoyed events and places reported by students help the teacher in the future planning of field trips.

2. Science Club

A science club provides opportunities to students to express their creative abilities in the field of science. The routine science programme may not cater to the individual needs and interests. Moreover, the classroom activities are usually formal and teacher-centred. Contrary to the classroom environment, the science club is informal and the pupils are free to choose their activities (Das, 1985). In other words, the classroom demands conformity and repression, while the science club facilitates freedom of expression of every individual.

Individual laboratory work at high school level is not feasible in a country like India. Therefore, science club should serve as a place for group and individual work. Science club activities improve students' comprehension and help to develop scientific hobbies. Participation in science club should never be imposed on the students. It should emerge as a need of the students. Otherwise, the basic purpose of the science club will be defeated.

Patnaik and Seetharamappa (1994) and several others (e.g., Sharma & Sharma 1971, Kohli, 1986) have listed objectives of science club. The major objectives are:

1. To provide opportunities for bringing forth students' hidden talents
2. To explore local resources and to learn and maintain the environment
3. To provide opportunities for the development of scientific skills
4. To popularize science among the ordinary people
5. To inculcate scientific attitude in pupils
6. To provide opportunities for training in scientific methods
7. To develop scientific interest among people and thereby developing scientific hobbies
8. To keep students in touch with the latest developments in science and their impact on human beings

Organisation of Science Club

Any organisation should have an organizational set up for its smooth functioning. Usually, the head of the institution is the patron of the science club. The students (members) of the club should meet the recurring expenditure. The science club should form two bodies -- a general body consisting of all students, and an executive committee. The executive committee should consist of the patron, sponsor, president, vice-president, secretary, assistant secretary, treasurer, librarian and publicity convener. The sponsor of the club will be the science teacher concerned. The duty of each office bearer should be clearly given in the constitution of the club. Other committees may also be formed depending upon the requirement of the club. The success of the activities of the club depends on the effective planning of the programme.

Duties and responsibilities of executive body

i. Prepare the action plan for carrying out activities of the club

ii. Meet as and when required to decide the programme of activities

iii. Evaluate all the activities of the club and present the same before the general body

iv. Prepare budgets, maintain accounts, etc.

v. Take decisions regarding membership

vi. Supervise activities of all committees formed.

Suggested science club activities

The science club can take up several activities. The one suitable to the club members and feasible with the available local resources should be selected. A few science club activities are listed below.

1. Guest lectures on topics of current importance
2. Seminars, symposia, panel discussions and debates
3. Maintaining bulletin boards
4. Conducting competitions such as quiz
5. Collection and preservation of samples of chemical compounds
6. Arranging demonstrations
7. Improvisations

8. Conducting science exhibition and science fairs
9. Observing days of scientific importance
10. Undertaking science projects
11. Organizing field trips
12. Helping in the science library
13. Organizing street plays to conscientise common man
14. Publishing school magazine in science

3. Science Fairs

Science fair is of great importance in the instruction of science in a non-formal way. It serves as a forum for the display of useful activities carried out by students. It provides an occasion for the parents and public to get acquainted with the school activities. Science fair helps in disseminating knowledge and in developing science consciousness among students and the community.

The objectives of science fair as suggested by NCERT (as cited in Vanaja, 2005) are:

i. To give impetus and encouragement to the students to tryout their ideas and apply their classroom learning to creative channels

ii. To provide opportunities to students to witness the achievements of their colleagues and thereby stimulate them to plan their own projects

iii. To popularize science activities among people so that further improvements in standards of performance may be achieved

iv. To give encouragement and recognitions to the bright and energetic students who have special talents

v. To identify and nurture the future scientists of India

vi. To provide the much needed forum for the activities of the science clubs

vii. To make the community get associated with the school

Levels of Science Fairs

Science fairs are organised at four levels. They are (1) institutional level, (2) district level, (3) state level, (4) regional level and national level.

(1) Institutional level science fair

Institutions organise science fairs annually where the students are allowed to display their projects, exhibits, etc. It provides an occasion for the interaction between teachers, parents and community. The winners will be sent to the higher-level science fairs.

(2) District level science fairs

The District Educational Officer conducts these fairs; annually, in consultation with NCERT/SCERT, which decides the themes and sub themes for the fair. The best projects or prize winning entries will be selected for entry into state level fairs.

(3) State level science fairs

Usually SCERT conducts State level science fair annually. Winners at state level will be allowed to participate in regional level or national level science fairs.

(4) Regional level and National level science fairs

The regional level science fairs are conducted by NCERT or agencies like Vishweshwariah Industrial and Technological Museum, Bangalore.

The NCERT conducts the national level science fair annually on the basis of the write-ups by students who participated in the state level fairs.

Organisation of Science Fair

The following factors should be considered while organising a science fair.

1. Planning

Careful planning is necessary for the successful conduct of a science fair. The following aspects have to be considered in the planning stage.

i. Aims and objectives of the fair

ii. Themes and sub themes of the fair

iii. Financing and sponsorship

iv. Location and time duration of the fair

v. Proper control and co-ordination of the fair

vi. Provision of various facilities

2. Distribution of work

The work and responsibilities should be distributed among various committees. There should be committees like

i. Advisory committee

ii. Programme committee

iii. Reception committee

iv. Publicity committee

v. Finance committee

vi. Administrative committee

3. Safety and first aid

To ensure the safety of the projects, exhibitors and the public safety rules should be strictly observed.

1. Electrical and fire safety rules should be observed. All electrical connections should be false free
2. No project should be permitted which may constitute a hazard to the public
3. First aid arrangements should be provided

4. Execution of the Science Fair

On the day of the fair following points should be kept in mind.

1. Each entrant should be given adequate space to setup the project
2. Facilities like water; electricity, etc. should be available wherever necessary
3. Projects of same category should be placed together
4. Directions for public who visit the fair should be given clearly

5. Judging

An expert team consisting of scientists, professors of science, etc., should judge the science fair. The NCERT has given the following criteria for judging the exhibits in the fair (cited in Vanaja, 2005).

1.	Scientific Approach	-	30 points
2.	Originality	-	20 points
3.	Technical skill and workmanship	-	20 points
4.	Thoroughness	-	10 points
5.	Dramatic Value	-	10 points
6.	Personal Interview	-	10 points
	Total	-	100 points

The participants of the fair must be aware of the judging criteria and the judges should stick on to the criteria. This would make the judgment reliable, valid, and uniform.

6. Evaluation

When the fair is over, there should be a thorough evaluation, participating members of all the committees to find out the extent of realisation of the pre-defined objectives of the fair. This evaluation will also help to identify the weaknesses in the organization of the fair, which could be avoided in the future.

Advantages of Science Fairs

i. Science fairs provide excellent opportunity for sharing science projects done by individuals, small groups or entire class with other students of the same school, other schools, parents and other members of the community.

ii. Science fairs can be a motivating force for individual as well as group work.

iii. Through science fairs, the talented students are recognized, rewarded, and stimulated.

iv. Science fairs help young people to utilise their time in a constructive way.

v. They develop a keen taste and interest for scientific investigation and in solving scientific problems.

Chapter XI

SCIENCE TEACHER

Teacher makes countless decisions in the classroom about the curriculum, instruction technique, classroom management, and standards of discipline (Heck & Williams, 1984; Johnson, 1990). The quality of decision-making depends on several factors such as knowledge of the foundations of curriculum, methodology of teaching, knowledge related to the specific classroom setting and the ability to diagnose the numerous factors that operate simultaneously in the classroom. Thus, science teachers have a wider range of roles to perform than teachers of other subjects do.

Good science teaching develops in children, the kinds of attitudes, ways of thinking and solid knowledge base that promote success in the real world. Enthusiastic, intelligent, and well-educated science teachers inspire and prepare students for the technological world. For science teaching to be effective, science teacher has to keep pace with the developments and s/he should constantly retrospect his/her performance. The classroom, library, laboratory, science club and science workshop activities make special pedagogical demands on the science teacher. Osborn and Freyberg (1985) have classified the roles of teacher into six - - (1) the teacher as a motivator, (2) the teacher as a diagnostician, (3) the teacher as a guide, (4) the teacher as an innovator, (5) the teacher as an experimenter and (6) the teacher as a researcher.

Qualities of a Science Teacher

Besides the academic qualifications prescribed by the government/authority/ employer concerned, a good science teacher should possess certain special qualities also. It is not easy to have all the good qualities in a science teacher. However, the science teacher should possess atleast certain general and special qualities. The qualities needed for a science teacher can be classified into two - - (1) general qualities and (2) special qualities.

1. General qualities

The qualities needed for a science teacher under this category is same as those qualities needed for teachers of other subjects. They may include the following:

a) Regular attendance and punctuality
b) Sincerity to cover the syllabus in time and conducting regular evaluation
c) Should possess a knowledge of educational psychology
d) Personal contact with students and special help to weak students
e) Availability to students even outside class hours
f) Insist on good discipline and good behaviour
g) Experiences joy in his/her work
h) Truthfulness and tolerance
i) Resourcefulness and always strive to improve competencies
j) Lack of bias/prejudice and value oriented
k) Self-confidence and strong will-power
l) Simple living and high thinking
m) Social skills such as empathy, co-operative mentality, respect for others, etc.
n) Willingness to attend seminars, workshops, etc. for professional growth

2. Special qualities

The special qualities needed for a science teacher are enumerated below:

a) Thorough knowledge of subject matter
b) Knowledge of history of science and innovations in science
c) Adequate knowledge of other related subjects
d) Well-versed in the latest techniques, strategies and methodology of teaching science
e) Practical skills to handle the apparatus and to manipulate equipments
f) Thorough knowledge and awareness regarding the system of examination and evaluation and the changing trends in these area
g) Sufficient practical skills in improvising apparatus
h) Taste for conducting co-curricular activities related to science
i) Willingness to do research related to one's own subject
j) Publication of books and articles in journals related to science
k) Knowledge of laboratory-precautions and first aid
l) Ability to handle gadgets such as computer, LCD, etc. and make use of ICT in education

Duties and Responsibilities of a Science Teacher

As a professional, a science teacher has to discharge various duties and responsibilities (Siddiqi & Siddiqi, 1983; Mangal, 1990). It can be summarised as given below:

The science teacher should

a) Plan the work for the whole year before the commencement of the academic year
b) Plan his/her lessons well in advance before each class
c) Organise science laboratory, science library and science museum
d) Facilitate curriculum transaction in various classes assigned to him in the school timetable
e) Guide and assist students in their classrooms, laboratory and library

f) Assign appropriate and relevant homework and assignment to students and assess them regularly

g) Inform students of the latest developments in science

h) Attend summer institutes, seminars, workshops and other in-service programmes

i) Organise various co-curricular activities such as, science fair, science exhibition, science excursion, field trip, nature walk, scientific hobbies, etc.

j) Actively assist in improving and developing science curriculum

k) Keep regular record of the progress of students

l) Subscribe and contribute to good science and educational journals such as School Science, Journal of Indian Education, Indian Education Review, etc.

m) Help and assist the school administration especially in the conduct of various school programmes

Professional Growth

The strength and success of an educational system depends on the quality of teachers. A teacher's personal qualities, educational qualifications, professional training, managerial skills, and the position he occupies in his institution and in the community contributes to the quality of teaching. A teacher is prepared for the profession before s/he enters it, but must also be prepared repeatedly to keep abreast with latest developments. The purpose of in-service/continuing education is to satisfy this need. The frontiers of human knowledge in various fields expand rapidly. There is, therefore, a need for continued study and growth that would raise the competence of the teacher on the job and in turn, increase the standard of the whole education system (Vedanayagam, 1989). The formal education and training is not sufficient and needs more in the form of professional growth of the teacher for doing justice with his/her students.

Meaning of professional growth

Professional growth means the growth and development of teachers' abilities, capacities and competencies for carrying out properly all his responsibilities related to the teaching profession (Mangal, 1990). It can be attained only through sincere efforts from the part of the teacher. S/he has to attend in-service/continuing education programmes such as attending refresher courses, seminars, workshops, etc., to excel in their profession.

In-service education

In-service education in a broad sense includes all experiences and activities provided for teachers and are designed to promote personal and professional growth while in service. The continuing education also has the connotation of the life-long education; of educating oneself throughout life, whether he is a student, teacher or a non- professional (Vedanayagam,1989). The in-service education programme can take up several forms and patterns depending on the purpose for which it is conducted, the resources and infrastructure available, and the duration of the course.

Need for in-service education

a) To provide opportunities for updating the knowledge of development in science and technology

b) To acquire improved understanding of pedagogical techniques

c) To give opportunity to practise new teaching techniques and share experiences with other teachers

d) To give teachers an exposure to new techniques and developments in Information and Communication Technology (ICT)

e) To suggest remedies for inadequacies of existing teacher education programmes

Some of the common types of in-service education are discussed below:

a) Professional meeting: Conferences of science teachers at the various levels will be helpful in exchanging ideas, innovations, research findings, etc., whereby they get updated for the present educational scenario. The National Science Teachers' Association

(NSTA) and state affiliates organise such conventions and meetings for teachers.

b) **Faculty meeting:** Administrators and supervisors must schedule an adequate number of faculty meetings during a school year. Each faculty meeting needs to pinpoint selected problems identified by teachers, discuss issues and means for improvement and solving these problems would help teachers do better in their profession.

c) **Content course:** These courses are conducted to upgrade the teachers in their specialisation in terms of knowledge of the latest developments, current issues and trends, their application and their relevance to teaching. Content courses are organised with the help of competent resource persons in a particular area of discipline, as the competency of the resource persons largely contributes to the success of the programme. During summer holidays, these courses are organised for a longer duration of 4-6 weeks and this gives time for real upgradation of the teachers in the concerned subject.

d) **Refresher course:** These are generally organised to give an opportunity to teachers to refresh and improve their knowledge of the subjects they teach and widen their experience in the methodology of teaching. The duration of the refresher course is generally three, four or five days.

e) **Summer institute:** It can be on one specific topic or area, covering invariably all aspects of the teaching-learning processes such as content, methodology, educational technology, and evaluation including practical aspects of laboratory work, field trips and experimentation. For example, summer institutes sponsored by the National Council of Educational Research and Training (NCERT), University Grants Commission (UGC), Academic Staff Colleges, etc.

f) **Workshop:** It means working in groups to complete a specified task within a stipulated time. The participants have a full share in all activities in the conduct of a workshop. The essential features of the workshop are the intensive consideration of practical problems of classroom teaching, informal working conditions, sharing of experiences with the peer group and the availability of a range of resources such as resource persons, books, journals, learning aids and equipment and apparatus for laboratory work. Outside one's own institution, workshops are being organised by NCERT, Universities, SCERTs, extension departments of training colleges, etc.

g) Seminar: These are gatherings of professionals with a major theme(s) for discussion, where experts in the field present their views. Such meetings are organised at various levels - - state, national, international, etc. Seminars are organised by agencies such as NCERT, Uuniversities, SCERTs, Colleges, etc.

Role of NCERT in Promoting Professional Growth

National Council of Educational Research and Training established in 1961, is an autonomous organisation, which plays a major role at the national level in the formulation and implementation of national policies and programmes in school education and teacher education. The council is fully financed by Government of India. At present, its organisational setup is composed of the following.

a) National Institute of Education (NIE): it is composed of various departments that cater to the need of science. NIE is situated at New Delhi.

b) Central Institute of Educational Technology (CIET): this institute engages in discovering and implementing the hardware and software technology for the improvement of education including formal and informal science education.

c) Regional Colleges of Education (RCE): These colleges are located at Ajmer, Bhopal, Bhuvaneswar and Mysore. These are residential institutions with adequate laboratory, library and other facilities.

d) Field Officers: NCERT has set up a number of field officers at the main places spread out in the whole country to provide effective liaison with the state education authorities as well as with the state level institutions such as, SCERT, State Institutes of Science Education (SISE), and Extension departments working in the training colleges for providing academic and training inputs to the school education system.

NCERT undertakes many programmes to impart quality in-service education to both elementary and secondary teachers. The major programmes organised by NCERT are (Mangla, 2001):

a) School based in-service education and training

b) Seminar programmes for elementary and secondary teacher educators

c) Orientation courses in microteaching and models of teaching

d) Annual conferences of State Boards of Education and SCERTs

e) Teacher motivated in-service education and training including participation in seminars, workshops, conferences, etc.

f) Publication of books, journals and periodicals

Role of SCERT

State Government have established in their respective states, State Council of Educational Research and Training (SCERT) for bringing qualitative improvement in school and teacher education. The guidance and help is available from the field officers of the NCERT located in the state.

State Institutes of Science established at a suitable place in the respective states by the state governments are mainly responsible for the planning, research, co-ordination and implementation of the work related with science education at the state level. Their functions include arranging in-service training programmes to science teachers, working as centre for conducting research studies in science education, implementing innovative ideas and programmes related with the study of science, preparing materials and aids for the teaching of science, working as guide and source for organising science education for students and masses, etc.

Chapter XII

MICRO-TEACHING

Micro-teaching is a teacher training technique which was first adopted at Stanford University, USA in 1961 by Dwight W. Allen and his co-workers. The technique of micro-teaching is based on Skinner's theory of operant conditioning. It is a training technique which requires student-teachers to teach a single concept or a few facts, using specified teaching skill, to a small number of pupils in a short duration of time. The most important point in micro-teaching is that teaching is practiced in terms of definable, observable, measurable and controllable teaching skills. According to Gage "teaching skills are specific instructional techniques and procedures that a teacher may use in the classroom. They represent an analysis of the teaching process into relatively discrete components that can be used in different combination in the continuous flow of the teacher's performance" (cited in Passi, 1976). The component teaching skills can be practised one by one under simplified teaching situations. The assumption behind micro-teaching technique is that once these component-teaching skills are mastered one by one, they can be integrated for real teaching.

Definitions of microteaching

Allen defines, micro-teaching as "a scaled down teaching encounter in class size and time" (cited in Singh & Sharma, 1987).

According to Bush, "micro-teaching is a teacher education technique which allow teachers to apply clearly defined teaching skills to carefully prepared lessons in a planned series of five to ten minutes encounters with a small group of real students, often with an opportunity to observe the result on a video tape" (cited in Mohan, 2002).

According to Passi and Lalitha "micro-teaching is a training technique which requires student-teacher to teach a single concept using specified teaching skill to a small number in a short duration of time" (cited in Passi, 1976).

According to Flanders, "micro-teaching programme is organised to expose the trainees to an organised curriculum of miniature teaching encounters, moving from the less complex to the more complex" (cited in Aggarwal, 1995).

From the above definitions, it can be understood that microteaching is a scaled down sample of teaching in which common complexities in the classroom-teaching are reduced in terms of - - (1) length of content, (2) class size, (3) number of skills used, and (4) number of students.

Phases in microteaching

Clift lists three phases of micro-teaching (cited in Aggarwal, 1995). The phases and the various processes which are to be performed by student-teachers under these phases are summarised as follows.

1. **Knowledge acquisition phase** (Pre-active phase)
   a) Observe the demonstration of skill
   b) Analyse and discuss the demonstration
2. **Skill acquisition phase** (Interactive phase)
   a) Prepare the micro-lesson
   b) Practice the skill (teach)
   c) Evaluate the performance
   d) Re-teach
3. **Transfer phase** (Post-active phase)
   a) Transfer of skills to link practice situation
   b) Transfer of skills to macro-teaching situation

Steps of Micro-teaching

In view of the above three phases the following steps are included in the micro-teaching procedure.

1. **Orientation of student-teachers -** The student teachers should be given necessary theoretical background about microteaching regarding the aspects given below:
   a) Concept of micro-teaching
   b) Significance of micro-teaching
   c) procedure of micro-teaching
   d) Requirements and settings needed for micro-teaching
2. **Discussion of teaching skills –** Here discussions are made with an emphasis on the following:
   a) Analysis of teaching into component teaching skills
   b) The rationale and role of these teaching skills in teaching
   c) The component teaching behaviours comprising various teaching skills
3. **Selection of a particular teaching skill –** A particular skill is defined to the student-teachers in terms of specific teaching-behaviours and the objectives with such behaviours aim at teaching.
4. **Presentation of a model demonstration lesson (on a particular skill) –** Depending upon the availability of the resources and type of skill involved, demonstration or model lesson can be given in a number of ways. A few suggestions are given below:
   a) By providing written material
   b) By exhibiting a film or a video tape
   c) By making the student-teachers listen an audio tape
   d) By arranging a demonstration from a live model; that is a teacher-educator or an expert demonstrate the use of the skill

5. **Observation of the model lesson and criticism –** An observation schedule designed for the observation of the specific skill is distributed among the student-teachers and they are also trained in its use before hand. Such observation of the model lesson and its relevant criticism provides desirable feedback to the student-teachers.

6. **Actual practice for the development of a particular skill –** The actual practice of the selected skill is carried out through the following steps - - (a) planning the micro-lesson, (b) teaching the micro-lesson (role playing), (c) feedback (critique conference), (d) re-planning the micro-lesson, (e) re-teaching, and (f) re-feedback. These steps are repeated till the student-teacher acquires the particular skill. Thus, the steps are collectively known as microteaching cycle. The steps involved in micro-teaching cycle are detailed below:

   a) **Planning the micro-lesson:** The student-teacher prepares a micro-lesson plan by selecting a suitable topic, concentrating on one skill at a time, by taking a small content and considering the behavioural components involved in the skill. The standard setting for a micro-class is as given below.

Number of pupils	:	5 to10
Type of pupils	:	real pupils or peers
Type of supervisors	:	teacher-educators and peers
Time duration	:	36 minutes

This duration is divided as follows:

For teaching session	:	6 minutes
For feedback session	:	6 minutes
For re-plan session	:	12 minutes
For re-teach session	:	6 minutes
For re-feedback session	:	6 minutes
Total	:	36 minutes

b) **Teaching the micro-lesson or role-playing:** The student-teacher teaches the prepared micro-lesson to a small group of pupils in simulated condition. The reaction shown by students will approximate the reality. The supervisor and peers can observe the class and can note down the observations in a specifically developed proforma. The lesson may be videotaped if facilities are available.

c) **Feedback:** In this session, feedback is given immediately to the student-teacher by the observers or by audio/video recorderings. The student-teacher observes and analyses his/her lesson with the help of supervisor, peer group and video clippings. This should be followed by suggestions to improve the skill.

d) **Re-plan session:** In the light of the feedback, the student-teacher re-plans the same lesson (or a different lesson) in order to use the skill attempted more effectively.

e) **Re-teach session:** The revised micro-lesson is re-taught to a different but comparable group using the same skill.

f) **Re-feedback session:** The student-teacher is provided with re-feedback on the re-taught micro-lesson. The verbal and non-verbal acts involved in teaching are unique in each situation. The small group interaction during the re-teach session could be drastically different from the first teach session. Therefore, a re-feedback brings in another dimensions as well as more acceptability to a particular component skill in teaching.

7. **Link-practice (Integration of teaching skills) –** It is concerned with the task of integrating several skills, individually mastered by the student-teacher. It is helpful in bridging the gap between training in isolated teaching skills and the real teaching situation faced by a teacher. Link-practice is employed here to practise the use of a few skills simultaneously before the full class teaching.

The steps involved in link-practice are similar to those of micro-teaching cycle. But in link-practice, the number of students in the class will be 20 to 25; duration of class will be 20 to 25 minutes; content of the lesson will include two or three concepts or ideas and the number of skills incorporated will be two or three. Genearlly students are taught in link-practice sessions, in which the problems of class management is in between that of a micro-teaching class and that of actual classroom situation. The planning, teaching and feedback sessions will be repeated until the student-teacher becomes able to employ the selected skills simultaneously.

Micro-teaching Skills

A teaching skill has been defined differently by different exponents. According to Passi (1976), "teaching skill is a group of teaching acts or behaviours intended to facilitate pupil's learning directly or indirectly." Many attempts have been made to list down different teaching skills. Allen and Ryan listed the following fourteen teaching skills (cited Aggarwal, 1995)

1. Stimulus variation
2. Set induction
3. Closure
4. Teacher silence and non-verbal cues
5. Reinforcing pupil participation
6. Fluency in questioning
7. Probing questions
8. Use of higher order questions
9. Divergent questions
10. Recognising and attending behaviours
11. Illustrating and use of examples
12. Lecturing
13. Planned repetition
14. Completeness of communication

The following six teaching skills have been selected for detailed study as they foster the teacher-pupil interaction at various stages of teaching process. They are given below:

1. Skill of introducing a lesson
2. Skill of probing questions
3. Skill of explaining
4. Skill of illustrating with examples
5. Skill of stimulus variation
6. Skill of reinforcement

1. Skill of introducing a lesson

When a teacher introduces a lesson, he provides a brief introduction about the lesson to the pupils. Introduction of a particular lesson includes the use of verbal and non-verbal behaviour, teaching aids and appropriate devices for making the pupils realise the need of studying the particular lesson. The components of the skill of introducing a lesson are:

a) **Use of previous knowledge:** The previous knowledge will be acquired from various sources such as classroom experiences, books, friends, etc. Mind cannot receive any new knowledge unless there is continuity with the relevant previous knowledge. Introducing a new lesson involves bringing the relevant previous knowledge in them to their conscious level.

b) **Use of appropriate devices:** The various techniques suitable for introducing a lesson are - - (1) use of examples or analogies, (2) questioning, (3) lecturing or describing or narrating or illustrating, (4) story telling, (5) role playing or dramatisation, (6) use of audiovisual aids, and (7) experimentation or demonstration. The appropriateness of such devices depends on its suitability to the age, grade, interest, culture, experiments, maturity of the pupils, and also on the unit to be taught.

c) **Maintenance of continuity:** Continuity refers to the sequence of idea or information being presented while introducing a lesson. Logical sequence should be ensured.

d) **Proper usage of relevant statements or questions:** A statement or a question, which a teacher uses while introducing a lesson, should be relevant and must be related to the aim of the lesson. Such statements or questions should contribute to the effectiveness of the skill in terms of establishing cognitive and affective rapport with the pupils.

2. Skill of probing questions

Ability to ask good questions has long been regarded as one of the chief merits for successful teaching. This skill of probing questions may be defined as the art of response management comprising a set of behaviours for going deep in to the pupils' responses with a view to elicit the desired response. The components of the skill of probing questions are:

a) **Prompting :** Prompting is a technique of going deep in to the pupils' initial response and leading him/her from incorrect or no response to the expected response, with a series of hints or prompts through step by step questioning process. Here the teacher neither supplies answer to the pupil nor does he redirect the question to some other pupils, but helps the pupil to answer he question him/herself. While using this technique, a teacher does not discourage the pupil for the no or wrong answers and the teacher help the pupil to arrive at the criterion response by means of systematic and step by step questions process.

b) **Seeking further information:** The technique of further information, which involves leading pupil from partially correct or incomplete response to the correct, complete or criterion response through questioning. For seeking information from the students, the teacher helps the pupil to clarify, elaborate or explain his initial response by asking questions such as 'give some examples,' 'make it more clear by giving some evidence,' etc.

c) **Refocusing:** This technique is generally used when the pupil gives a correct response. The teacher relates the answer with the topic already covered in the class. This technique enables the pupil to view his/her response in relation to other similar situations.

d) **Redirecting:** This technique is applied in a 'no response' or 'incomplete response' situation. It involves putting or directing the same question to several pupils for response. This can be used for the purpose of probing and for increasing pupil participation.

e) **Increasing critical awareness:** This technique is applicable in a correct response situation. This involves asking 'how' and 'why' of a completely correct or expected response. The teacher asks the pupil to justify his/her response rationally. Therefore, this technique elicits a rationale for his initial response.

A sample micro-lesson on skill of probing questions is given in Appendix VI.

3. Skill of explaining

Explaining can be defined as an activity to bring about an understanding about a concept, principle, etc. It is an activity to fill up a gap in someone's understanding. Explaining depends upon the type of past experience, the type of the new phenomenon, and the type of relationship between them. In a classroom, the teacher explains a phenomenon or an idea in order to bring about or increase understanding in the pupils about it. The skill involves a number of desirable and undesirable behaviours. A teacher has to increase the desirable instances and try to avoid undesirable ones. The components of the skill of explaining are:

a) Desirable behaviours:

(i) **Using explaining links:** This involves using linking words and phrases in the statements of an explanation. They are generally conjunctions or prepositions which explicitly indicate the cases, consequences, reasons behind, space sequence, time sequence, means or purposes of an event, concept, action or condition. The following are some of the explaining links which are generally used - - the result of, therefore, hence, as a result of, consequently, that's why, due to, this is how, in order to, since, because, so that, why, but, their, etc.

(ii) Using beginning statements: Generally, before an explanation certain statements are made for setting the minds of the listeners. The beginning statements create mental readiness on the part of pupils to listen to what is going to be explained.

(iii) Using concluding statements: After the explanation, certain statements are made which conclude the whole explanation. The concluding statements or summarising statements help in consolidating what has been explained.

(iv) Testing pupils' understanding: This behaviour of the teacher involves putting questions to pupils to test whether or not they have understood what has been explained.

b). Undesirable Behaviours:

(i) Stating irrelevant statement: While explaining, a statement becomes irrelevant when it is not related to and does not contribute to the understanding of the concept or phenomenon being explained. Such statements distract the attention of students from the subject of explanation and this lead to confusion.

(ii) Lacking in continuity: This refers to break in the sequence of ideas or information presented during explaining. During explaining, continuity breaks in the following situations :

(a) When a statement is not logically related to the previous statement

(b) When an already covered topic referred to without showing its relationship

(c) When there is no sequence of place or space or time

(d) When the statements are irrelevant

(iii) Using inappropriate vocabulary, vague words and phrases: This involves using terms unknown to the most of the pupils of that age group and grade level. Sometimes while explaining, a teacher uses such words and phrases which indicate that s/he is failing to make something explicit. For example, I mean, actually, probably, you see, you know, almost, etc.

(iv) Lacking in fluency: It occurs when a teacher speaks incoherently. There is lack of fluency when a teacher speaks half sentences or reformulates in the midway of a sentence or a statement. Lack of fluency not only distracts pupil's attention but also hinders their understanding of the subject of explanation.

4. Skill of illustrating with examples

Skill of illustrating with examples may be defined as the art of judicious selection and proper presentation of suitable examples in order to generalise a concept or idea with a view to its understanding and proper application. The skill is more important as it takes the learners from known to unknown. It also involves the principle of securing and sustaining the attention of pupils. The components of the skills of illustrating with examples are:

a) Formulating simple examples: Simple examples are those examples which are based on pupils' previous knowledge and suitable to their maturity. Teacher should try to give examples from the previous knowledge/experience of pupils in order to make the idea, concept or principle clear and understandable to pupils.

b) Formulating examples relevant to rule or concept: It refers to the applicability of the examples to the rule or concept which the teacher has to illustrate. Irrelevant examples not only lead to confusion, but also hinder the understanding of the rule or concept which they illustrate.

c) Formulating interesting examples: An example is said to be interesting if it can arouse curiosity and interest in pupils. Examples will be interesting if they are suitable to the age group and maturity level of pupils.

d) **Using appropriate media for examples:** Examples can be classified in to verbal and non-verbal. Verbal examples are those given verbally. They include giving analogies, story telling, etc. Non-verbal media include objects, models, pictures, diagrams, maps, sketches and experimental demonstrations. Teacher should select appropriate media for developing examples.

e) **Using examples by inductive-deductive approach**: By inductive approach a teacher can easily clarify a concept or rule to pupils. But this approach does not help the teacher to verify whether or not the pupils have understood the concept. For this purpose, deductive approach is necessary. It involves giving or eliciting a number of examples after the concept has been stated. So it is better to follow inductive-deductive approach for illustrating with examples.

5. Skill of stimulus variation

The skill of stimulus variation can be defined as deliberate changes in the attention drawing behaviours of the teacher in order to secure and sustain pupils' attention towards the lesson at high level. The attention drawing behaviours included in the skill of stimulus variation are:

a) **Teacher movement:** In order to secure and sustain attention of pupils a teacher has to move about in the class. Movements should be purposeful and within the limit so that pupils attention level is maintained high.

b) **Teacher gestures:** Using the movements of heads hand and body, the teacher will be more expressive and dynamic in his/her presentation in the class. The oral message is less effective in conveying meaning than oral message combined with gestures. Gestures can be made by movements of the parts of the body to direct attention, to emphasise importance, to explain emotions, or to indicate shapes, sizes, movements, etc.

c) **Change in speech pattern:** Whenever a teacher wants to express emotions or feelings, s/he can modulate his/her voice. This sudden variation in the stimulus will attract the attention of pupils. Thus by making sudden or radical changes in tone, volume or speed of the communication a teacher can draw the attention of students in a better manner.

d) **Change in sensory focus:** The behaviours that direct or focus pupils attention to the particular point can include certain verbal statements (verbal focusing) or gestures or movements (gestural focusing) and both verbal statements and gestures (verbal and gestural focusing). The simultaneous use of verbal and gestural focusing is found by experience to be more effective than either of them alone.

e) **Change in interaction style:** In a classroom there can be three types of interaction among pupils and teacher - - (a) teacher-group interaction, (b) teacher-pupil interaction, and (c) pupil-pupil interaction.

f) **Pausing:** Pausing means short break or introducing silence during talk. This sudden behaviour of the teacher will draw pupils' attention towards the teacher and hence towards the lesson.

g) **Oral-visual switching**: If there is a change in the medium through which the teacher gives information to the pupils, generally pupils' attention will be drawn towards it. Hence, such frequent changes help the teacher to sustain pupils' attention to what s/he is conveying.

Example:

a. Oral ← → oral-visual

b. Oral ← → visual

c. Visual ← → oral-visual

Observation schedule for skill of stimulus variation

Components	**Coding** (in minutes)												**Rating** Not at all → Very much						
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	0	1	2	3	4	5	6
Teacher movements																			
Teacher gestures																			
Change in speech pattern																			
Change in sensory focus																			
Change in interaction style																			
Pausing																			
Oral – visual switching																			

6. Skill of reinforcement

Skill of reinforcement may be defined as the art of judicious and effective use of reinforcers by a teacher for influencing pupils' behaviour in the desired direction; directed towards maximum pupil-participation. There are various ways in which the teacher can reinforce the pupils' desirable behaviour. Skill of reinforcement involves increased use of positive reinforcers and avoids the use of negative reinforcers. The component skills of skill of reinforcement are:

a) **Positive verbal reinforcement:** Positive verbal reinforcers refer to those verbal behaviours of the teacher that brings positive reinforcement.

(i) The use of words such as 'good,' 'very good,' 'fine,' 'yes,' 'well done,' 'excellent,' 'right,' etc. are examples of verbal reinforcement.

(ii) Repeating and rephrasing pupil's responses

(iii) Use of extra verbal cues such as 'um um,' 'aha,' etc.

b) **Positive non-verbal reinforcement:**

(i) Use of nonverbal expressions like nodding of head, smiling, moving towards the responding pupil, keeping eyes on the pupil, giving ears to the pupil indicating that attention is being paid to the pupils' words

(ii) Writing the responses of the pupil on the blackboard

c) **Negative verbal reinforcement:** Negative verbal reinforcement refers to the verbal behaviour of the teacher that bring about negative reinforcement. This type of reinforcement interferes with the learning of the pupils. Avoid discouraging expressions such as 'wrong,' 'incorrect,' 'stop it,' 'nonsense,' 'I don't like what you are doing,' 'do something else,' 'that is not good,' etc.

d) **Negative non-verbal reinforcement:** Negative non-verbal reinforcers are those non-verbal behaviours of the teacher that bring about negative reinforcement. Following types of reinforcers should be avoided by the teacher - - frowning, staring, moving away from the responding pupil, keeping eyes on the pupil with discouraging looks, not looking at the responding pupil, tapping foot impatiently and walking around, etc.

e) **Inappropriate or wrong use of reinforcers:** The following undesirable behaviours should be avoided by the teacher.

(i) Using reinforcers when not needed

(ii) Not using reinforcers when needed

(iii) Using the reinforcing in a less or excess amount than desired

(iv) Encouraging or reinforcing only a few responding pupils.

Chapter XIII

NATIONAL TALENT SEARCH SCHEME

National Council of Educational Research and Training (NCERT, established in 1961) initiated a programme to identify and nurture the talented students at the school level in 1963. However, the scheme called National Science Talent Search Scheme (NSTSS) was successfully implemented in the year 1964. The purpose of this scheme was to identify talented students and awarding them with scholarships. During the first year of the implementation of the scheme, it was confined to the Union Territory of Delhi and only 10 scholarships were awarded to the Class XI students. Subsequently, the scheme was extended to all the states and the union territories in the country with 350 scholarships for the students of Class XI.

Objectives of National Science Talent Search Scheme

The main objectives of the scheme are (Rajan, 1999):

a. To identify secondary school students who possess creative abilities in the scientific field

b. To stimulate scientific interest among pupils by competitive processes and recognition of merit

c. To encourage schools to take more active interest in the search for scientific ability

d. To quicken awareness in schools of the need for providing challenging opportunities to the talented students in science

e. To help in building up a body of future-scientists who will contribute to the scientific advancement of the nation in the fields of both pure and applied sciences

The scheme seeks to assess:

a. The pupils' aptitude for science
b. The pupils' powers of scientific reasoning and skill in scientific experimentation
c. The pupils' ability to apply knowledge; to analyse and interpret scientific data
d. The pupils' ability to express scientific concepts clearly and precisely
e. The pupils' creativeness and mental alertness in the investigation of the scientific phenomena
f. The pupils' awareness of the basic nature of science
g. The pupils' knowledge about the recent developments in the various branches of pure and applied sciences
h. The pupils' skill to devise and develop some original ideas experimentally

National Science Talent Search Examination

As part of NSTSS, NCERT organised National Science Talent Search Examination (NSTSE) as a national level scholarship programme in India every year to identify and nurture talented students. The programme was open to students of Indian nationality. Only students studying in Class VIII and Class X standards were eligible for appearing in the selection process. It was widely regarded as the most prestigious examination at high school level in the country.

These scholarships were awarded based on a written examination, a project report and an interview. The written examination comprised of a Science Aptitude Test and an Essay on a given scientific theme. The candidates were to submit the project report at the time of the written examination. A stipulated number of candidates selected based on these three components were then subjected to personal interview. The performance of the candidates on these four components was considered for awarding scholarships. These scholarships were awarded for pursuing education only in basic sciences up to doctoral level.

National Talent Search Scheme

With the introduction of 10+2+3 pattern of education, NSTSS also underwent a paradigm shift in the year 1976. It was no longer confined to only basic sciences but was extended to social sciences, engineering and medicine as well. It was renamed as National Talent Search Scheme (NTSS). Since the education system in India was undergoing a change, the scheme was made open to the students of Classes X, XI and XII and separate examinations were conducted for each class. The number of scholarships was raised to 500. The selection procedure was also changed. In the National Talent Search Examination (NTSE) the candidates are to appear for two objective-type written tests namely; the Mental Ability Test (MAT) and the Scholastic Aptitude Test (SAT). A predetermined number of candidates qualifying these two tests were subjected to a face-to-face interview. The final awards were made based on composite scores obtained in the MAT, the SAT and the interview.

The number of scholarships was again enhanced from 500 to 550 in the year 1981. These 50 scholarships were exclusively meant for Scheduled Castes (SC) and Scheduled Tribes (ST) candidates. The number of scholarships was again increased to 750 in the year 1983 with a provision of 70 scholarships especially for SC/ST candidates. This arrangement continued until the scheme was decentralized in the year 1985. Yet another change in the scheme was effected from the year 2000 wherein the number of scholarships was raised from 750 to 1000 with the provision of reservation for SC and ST candidates based on the national norms of 15% and 7.5% respectively.

The scheme was partially decentralised in 1985 and was confined to only class X. Under the new arrangement, the selection of candidates for the awards became a two-tier process - - the first tier conducted at state level and the second tier at national level.

The states got complete autonomy to design and conduct their written examinations. However, they were advised to follow the national pattern, which comprised MAT and SAT. The MAT, which consisted of 100 multiple choice type questions, was to be attempted by all the candidates. The SAT consisted of 25 multiple choice type questions each on eight subject areas namely Mathematics, Physics, Chemistry, Biology, History, Geography, Civics and Economics. The candidates could choose any four out of these eight subjects and had to answer 100 questions in the SAT.

A fixed number of candidates who qualified at the national level examination were called for face-to-face interviews. The award of scholarships was finally determined based on the candidates' scores obtained in all three components namely the MAT, the SAT and the Interview.

A crucial modification in the scheme was again made in the year 1995 when the provision of choice in the SAT was abolished and all the subjects were made compulsory. These subjects were Science, Social Science and Mathematics with 40, 40 and 20 questions respectively. The scholarships under the present scheme are awarded to the candidates for pursuing courses in sciences and social sciences up to doctoral level and in professional courses like medicine and engineering up to second-degree level, subject to the fulfilment of the conditions provided in this brochure.

Eligibility

Before 2006, all students studying in Class X in any type of recognised school were eligible to appear at the state level examination from the state in which the school is located. The state can impose any other eligibility condition for appearing in the screening examination like any qualifying percentage of marks in the previous annual examination, etc. However, from 2006 onwards, a separate examination for Class VIII is conducted. More than 1,50,000 students appear for the screening examination of the NTSE every year. From 2006 National Talent Search examination is held at the end of Class VIII. For students who have passed Class VIII before 2006-07, however, the NCERT decided to conduct two more NTS examinations for the students reaching class X for selection in years 2007 and 2008.

Syllabus

There is no prescribed syllabus for the NTSE examination. However, the standard of items conforms to the level of CBSE Class X Public Examinations. There are also many prescribed books that aid students appearing for this examination.

Scheme of Testing

From 2008 onwards, the maximum marks obtainable for the NTSE were 90 in both the MAT and the SAT. The passing marks are 40% (36 marks). The 90 marks in the SAT were split as follows: -Mathematics: 20 marks -Science: 35 marks -Social Sciences: 35 marks.

Scholarship

The students who qualify for the interview are eligible for scholarship. The amount of scholarship has been enhanced to Rs. 500/- per month for all the students studying in Class IX onwards (irrespective of the class/ course) except for Ph.D., wherein it is paid as per UGC norms. The older systems of book grant and the criterion of parental income for deciding payment of scholarship were discontinued.

The scholarships will be provided to the students studying in Classes IX to XII and up to Ph.D. level to those students who will pursue their courses in Basic and Social Sciences including Commerce. Scholarship will be given up to Masters Degree level that pursues professional courses like Engineering, Medicine, Law, Management, etc.

Chapter XIV

FAMOUS SCIENTISTS AND THEIR CONTRIBUTIONS

1. Galileo Galilei (1564 – 1642)

The great scientist Galileo Galilei was born on 15th February 1564 at Pisa, Italy. He was deeply interested in the study of nature and science. He helped to unlock many secrets of astronomy and natural motion. He believed that the planets revolved around the sun, and not the Earth. The Church of Rome denounced Galileo as a heretic. He faced the inquisition and was forced to renounce those beliefs publicly, though later research, of course, proved him correct and Church later recognised the validity of Galileo's work. This renowned astronomer and mathematician died on 8th January 1642.

Major contributions of Galileo

(1) Discovery of the isochronal nature of pendulum: At the age of 19 in the cathedral of Pisa, he timed the oscillations of a swinging lamp (chandelier while candles were lit in the church) by means of his pulse beats and found the time for each swing to be the same, no matter what the amplitude of the oscillation, thus discovering the isochronal nature of the pendulum, which he verified by experiment.

(2) Invention of the first high-powered astronomical telescope: Galileo succeeded in making a workable and sufficiently powerful telescope with a magnifying power of about 40. Using this telescope he gathered astonishing evidence about mountains on the moon, about moons circling Jupiter, and about an

incredibly large number of stars, especially in the belt of the Milky Way.

(3) Discovery regarding velocities of falling bodies: He disproved the Aristotle's proposition that articles of different weights when dropped from a height would reach ground at different times based upon their weights, heavier first and the lighter later. Galileo himself dropped two iron balls one weighing 100 pounds and other one pound from the seventh floor of the 180 feet high Leaning Tower of Pisa (Garg, 1992). Both the balls reached the ground simultaneously thereby empirically disproving Aristotle's long revered writings. The observation that all bodies fall at the same speed in vacuum is one of Galileo's ideas that led to the laws of motion and eventually to relativity theory.

(4) Discoveries in astronomy: Galileo discovered that the moon, shining with reflected light, had an uneven, mountainous surface and that the Milky Way was made up of numerous separate stars. In 1610, he discovered the four largest satellites of Jupiter, the first satellites of a planet other than Earth to be detected. He observed and studied the oval shape of Saturn, the phases of Venus, and the spots on the sun. His investigations confirmed his acceptance of the Copernican theory of the solar system, that the sun to be the central body and the earth a moving body revolving with the other planets about it (heliocentrism).

(5) Invention of a horse-powered pump to raise water

(6) Described the true parabolic paths of cannonballs and other projectiles

(7) Explained the hydrostatic principles of balancing

(8) Studies on centre of gravity of various solids

(9) Discovery of thermometer

2. Isaac Newton (1642 – 1727)

Sir Isaac Newton, mathematician and physicist, one of the foremost scientific intellects of all time was born on 25th December 1642 at Woolsthorpe, in Lincolnshire, England. He was sent to school at the age of 12 where he did not do well. At the age of 19 he joined Trinity College, Cambridge and graduated in 1665. At the age of 27 he became Professor of Physics in the Trinity College (Anthony, 1963). He was selected Fellow of Royal Society in 1672. In 1703, he became the president of the Royal Society and continued in that position until his death in 1727.

Major contributions of Newton

(1) Works on gravitation and mechanics: Newton identified gravitation as the fundamental force controlling the motions of the celestial bodies. He calculated the relative masses of heavenly bodies. He explained tidal ebb and flow and the precession of the equinoxes from the forces exerted by the Sun and Moon.

(2) Laws of motion: Newton postulated that: (1) all bodies attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them, (2) every body continues to be in a state of rest or of uniform motion unless it is acted upon by an external force and (3) every action will have an equal and opposite reaction. These propositions are popularly known as Newton's laws of motion.

(3) Theory of fluids: Newton solved problems of fluids in movement and of motion through fluids. From the density of air, he calculated the speed of sound waves.

(4) Refraction of light: He investigated the refraction of light and proved that sunlight is a combination of seven colours. The mixture of these seven colours produces white light, which was demonstrated by the Newton's colour disc. He postulated that light consisted of streams of minute particles, called, "corpuscles" and suggested corpuscular theory of light.

3. Antoine Laurent Lavoisier (1743 – 1794)

Antoine-Laurent de Lavoisier was born on 26th August 1743 in Paris, France. By education and training he was a lawyer (Anthony, 1963), prominent in the histories of chemistry, finance, biology, and economics. At the age of 25, he was elected a member of the French

Academy of Sciences. Because of his prominence in the pre-revolutionary government in France, he was beheaded on 8th May 1794 at the height of the French Revolution. His contributions are considered the most important in advancing chemistry to the level of physics and mathematics during 18th century.

Major contributions of Lavoisier

(1) Thermodynamics and the nature of combustion: He demonstrated that burning is a process that involves the combination of a substance with oxygen. Lavoisier demonstrated the role of oxygen in the rusting of metal and in respiration of animals and plants. Lavoisier showed that respiration is essentially a slow combustion of organic materials using inhaled oxygen. Lavoisier's explanation of combustion disproved the "Phlogiston theory", which postulated that materials release a substance called phlogiston when they are burned.

(2) Composition of water and air: Lavoisier studied the composition of water and air, which at that time were considered elements. He identified that the components of water are oxygen and hydrogen, and that air is a mixture of gases, primarily nitrogen and oxygen.

(3) Naming of Oxygen: He demonstrated that "air" is responsible for combustion and it is the source of acidity. In 1779, he named the part of "air" responsible for combustion as oxygen.

(4) Law of conservation of mass: He showed that, although matter can change its state in a chemical reaction, the quantity of matter is the same at the end as at the beginning of every chemical change. These experiments lead to the law of conservation of mass, which Lavoisier was the first to state.

(5) Allotropy in elements: Lavoisier introduced the possibility of allotropy in elements when he discovered that diamond is a crystalline form of carbon.

(6) Analytical chemistry and chemical nomenclature: Lavoisier contributed to devise a systematic nomenclature of chemical compounds and this system, facilitated communication of

discoveries between chemists of different backgrounds and is still largely in use today, including names such as sulphuric acid, sulphates, and sulphites.

4. Robert Boyle (1627 – 1691)

Robert Boyle was born on 25th January 1627 in Lismore Castle, in County Waterford, Ireland. He was a natural philosopher, chemist, physicist, inventor, and was noted for his works in physics and chemistry. Among his works, *The Sceptical Chymist* is seen as a cornerstone book in the field of chemistry. Through this publication Boyle questioned the Aristotelian conception of four elements - - earth, air, water and fire (Anthony, 1963). He was one among the first members of the council of the Royal Society. He died on 30th December 1691.

Major contributions of Boyle

(1) The enunciation of Boyle's law.

(2) Discovery of the part taken by air in the propagation of sound.

(3) Investigations on, the expansive force of freezing water.

(4) Conducted studies on, specific gravities and refractive powers, crystals, electricity, colour and hydrostatics.

(5) Proposed the view of elements as, the indecomposable constituents of material bodies. Distinguished mixtures and compounds.

(6) Coining the term "analysis": He made considerable progress in the technique of detecting the ingredients of compounds, and he called the process by the term analysis. He further postulated that the elements were ultimately composed of particles of various sorts and sizes.

(7) Boyle studied the chemistry of combustion and of respiration, and conducted experiments in physiology.

5. Dmitri Ivanovich Mendeleev (1834 – 1907)

This Russian chemist was born on 8th February 1834 in Tobolsk, Siberia. He is credited as being the creator of the first version of the periodic table of elements. Unlike other contributors to the table, Mendeleev predicted the properties of elements yet to be discovered. Mendeleev became Professor of Chemistry at the Saint Petersburg Technological Institute and the University of St. Petersburg in 1863. In 1865 he became Doctor of Science for his dissertation on "the combinations of water with alcohol". By 1871 he transformed St. Petersburg into an internationally recognised centre for chemistry research. Though Mendeleev was widely honoured by scientific organisations all over Europe, including the Copley Medal from the Royal Society of London, he resigned from St. Petersburg University on 17thAugust 1890. In 1893, he was appointed Director of the Bureau of Weights and Measures. He died on 2nd February 1907. The Mendeleev craters on the Moon, as well as element number 101 the radioactive mendelevium, are named after him.

Major contributions of Mendeleev

(1) Classification of elements: He arranged elements in the order of atomic mass while working on the idea that there must be a relation between the mass and properties of chemical elements. He devised a periodic table in which the elements were arranged in columns and rows so that each column includes elements of related character. The table contained several vacant spaces and he predicted the properties of the undiscovered elements that would occupy those spaces (Anthony, 1963, p. 220).

(2) Worked on the capillarity of liquids and the working of the spectroscope.

(3) Formulated new state standards for the production of vodka; it should be produced in the ratio of one molecule of ethyl alcohol diluted with two molecules of water, giving a dilution by volume of approximately 38% alcohol to 62% water.

(4) Mendeleev studied origin of petroleum and concluded that hydrocarbons are abiogenic and form deep within the earth. He investigated the composition of oil fields, and helped to install the first oil refinery in Russia.

(5) Mendeleev is one of the founders, of the Russian Chemical Society.

(6) He worked on the theory and practice of protectionist trade and on agriculture.

(7) Mendeleev is given credit for the introduction of the metric system to the Russian Empire.

(8) He invented pyrocollodion, a kind of smokeless powder based on nitrocellulose.

6. Michael Faraday (1791 – 1867)

Michael Faraday was born on 22nd September 1791at Newington Butts, England. He was a chemist and physicist (or natural philosopher, in the terminology of that time) who contributed to the fields of electromagnetism and electrochemistry and is popularly known as "father of electromagnetic induction". Although Faraday received little formal education and knew little of higher mathematics, such as calculus, he was one of the most influential scientists in history. He was elected a member of the Royal Society in 1824. Faraday was the first and foremost Fullerian Professor of Chemistry at the Royal Institution of Great Britain, a position to which he was appointed for life. In June 1832, the University of Oxford granted Faraday a Doctor of Civil Law degree (honorary). The SI unit of capacitance, farad and Faraday constant are named after him. This famous scientist died on 25th August 1867. The former UK Faraday Atmospheric Research Station in Antarctica was named after him.

Major contributions of Faraday

(1) Faraday studied the magnetic field around a conductor carrying a dc supply, and established the basis for the magnetic field concept in physics.

(2) He discovered electromagnetic induction, and established the laws of electromagnetic induction.

(3) Faraday constructed the electric dynamo, the ancestor of modern power generators.

(4) He discovered diamagnetism: In 1845, he discovered the

phenomenon that he named diamagnetism, and what is now called the Faraday effect. The plane of polarisation of linearly polarised light propagated through a material medium can be rotated by the application of an external magnetic field aligned in the propagation direction. This established that magnetic force and light were related.

(5) Experiments on fundamental nature of electricity: Faraday used static batteries, and animal electricity to produce the phenomena of electrostatic attraction, electrolysis, magnetism, etc. He concluded that, contrary to scientific opinion of the time, the divisions between the various "kinds" of electricity were illusory. Faraday instead proposed that only single "electricity" exists, and the changing values of quantity and intensity (voltage and charge) would produce different groups of phenomena.

(6) He discovered electrolysis and derived laws of electrolysis.

(7) He established that magnetism could affect rays of light and that there was an underlying relationship between the two phenomena.

(8) His inventions of electromagnetic rotary devices formed the foundation of electric motor technology, and it was largely due to his efforts that electricity became viable for use in technology.

(9) Faraday was the first to report what later came to be called metallic nanoparticles. In 1847 he discovered that the optical properties of gold colloids differed from those of the corresponding bulk metal. This was probably the first reported observation of the effects of quantum size, and might be considered the birth of nanoscience.

(10) Faraday cage: In his work on static electricity, Faraday demonstrated that the charge only resided on the exterior of a charged conductor, and exterior charge had no influence on anything enclosed within a conductor. This is because the exterior charges redistribute such that the interior fields due to them cancel. This shielding effect is used in what is now known as a Faraday cage.

(11) Faraday discovered benzene (which he called bicarburet of hydrogen).

(12) He invented the system of oxidation numbers.

(13) Faraday determined the composition of the chlorine clathrate hydrate.

(14) He popularised terminology such as anode, cathode, electrode, and ion.

(15) Faraday made a special study of chlorine, and discovered two new chlorides of carbon.

(16) He succeeded in liquefying several gases.

(17) He investigated the alloys of steel.

(18) Faraday produced several new kinds of glass intended for optical purposes.

(19) He invented an early form of what was to become the Bunsen burner, which is used almost universally in science laboratories as a convenient source of heat.

(20) In 1820 Faraday reported on the first synthesis of compounds made from carbon and chlorine, C_2Cl_6 and C_2Cl_4.

7. Chandrasekhara Venkata Raman (1888 – 1970)

C. V. Raman was born at Trichinapally in India on 7th November 1888. He was the first Indian scholar who completed all his studies in India to receive the Nobel Prize. Raman has been honoured with a large number of honorary doctorates and memberships of scientific societies. He was elected a Fellow of the Royal Society in 1924. For his pioneering work on scattering of light, he won the Nobel Prize for Physics in 1930. He became Professor at the Indian Institute of Science at Bangalore in 1933, and since 1948 he was the Director of the Raman Institute of Research at Bangalore, established and endowed by him.

Major contributions of C. V. Raman

(1) He carried out his experimental research in acoustics and optics

at the laboratory of the Indian Association for the Cultivation of Science at Calcutta.

(2) He founded the Indian Journal of Physics in 1926, of which he was the editor.

(3) Study on scattering of light: In 1928, he discovered that when an intense beam of monochromatic light is scattered by a liquid, the spectrum of the scattered radiations contains lines whose wavelengths are longer and shorter than the incident radiation. This finding is known as Raman effect, for which he received Nobel prize in 1930.

(4) Studies on the diffraction of light by acoustic waves of ultrasonic and hypersonic frequencies.

(5) He established the Raman Research Institute in Bangalore in 1949, where he worked until his death on 21st November 1970.

(6) In 1948 Raman, through studying the spectroscopic behaviour of crystals, approached fundamental problems of crystal dynamics in a new manner. His laboratory was dealing with the structure and properties of diamond and the structure and optical behaviour of numerous iridescent substances (labradorite, pearly felspar, agate, opal, and pearls).

(7) He studied optics of colloids, electrical and magnetic anisotropy, and the physiology of human vision.

8. Max Karl Ernst Ludwig Planck (1858 – 1947)

The famous German physicist Max Planck was born on 23rd April 1858 in Kiel, Germany. He is considered as the founder of quantum theory. He was educated at Munich and Berlin universities and later he worked there as professor of physics. In 1918 he was awarded the Nobel prize in physics in recognition of his quantum theory.

Major contributions of Max Planck

(1) Thermodynamic basis for Arrhenius theory: He proposed a thermodynamic basis for Arrhenius theory of electrolytic

dissociation.

(2) Theory of black-body radiation: The experimentally observed black-body spectrum could be well described by his famous black-body radiation law.

(3) Quantum theory of radiation: Around the year 1900, Planck established a theory regarding the exchange of energy between matter and electromagnetic radiation. Electromagnetic radiation is absorbed by matter only in the form of discrete packages. The amount of energy in a package depends on the frequency of the radiation. This package of energy is called quantum. The energy could only be a multiple of an elementary unit $E = h\nu$, where h is Planck's constant, and ν is the frequency of the radiation. On the basis of this he explained the phenomenon of photo electric effect. The discovery of Planck's constant enabled him to define a new universal set of physical units (such as the Planck length and the Planck mass), all based on fundamental physical constants.

9. Albert Einstein (1879 – 1955)

Albert Einstein was born on 14th March 1879(1879-03-14) at Württemberg, Germany. He was perhaps the most well-known scientist of the 20th century. In 1905 Einstein received his doctorate from the University of Zürich for a theoretical dissertation on the dimensions of molecules. He received Nobel prize in physics in 1921, Copley medal in 1925, and Max Planck medal in 1929. He is best known as the creator of the special and general theories of relativity and for his bold hypothesis concerning the particle nature of light. Einstein died on 18th April 1955 at Princeton, USA.

Major contributions of Einstein

(1) Brownian motion: He made significant predictions about the motion of particles that are randomly distributed in a fluid.

(2) Photoelectric effect: When light energy of certain frequency falls on surface of metals such as cesium electrons are emitted. He was awarded Nobel prize in Physics, considering this discovery.

(3) The special theory of relativity: A reliable explanation for the

way radiation and matter interact when viewed from different inertial frames of reference, that is, an interaction viewed simultaneously by an observer at rest and an observer moving at uniform speed.

(4) The general theory of relativity: It deals with problems in which one frame of reference is accelerated with respect to another frame of reference.

(5) Mass-energy equation: He proposed the famous equation $E = mc^2$ which relates mass and energy. This was the principle behind the development of atom bomb.

10. Prafulla Chandra Ray (1861 – 1944)

Prafulla Chandra Ray was a Bengali academician, a distinguished chemist and entrepreneur. He was born on 2nd August 1861, in Khulna District (now in Bangladesh) and died on 16th June 1944. He was the founder of Bengal Chemicals and Pharmaceuticals, India's first pharmaceutical company. He was reputed as a successful, inspiring and popular teacher. Acharya Prafulla Chandra College and Acharya Prafulla Chandra Ray Polytechnic, both in Kolkata, are named after him.

Major contributions of Prafulla Chandra Ray

(1) Invented a new stable chemical compound - mercurous nitrite: This path breaking work made way for a large number of investigative papers on nitrites and hyponitrites of different metals, and on nitrites of ammonia and organic amines. This entire endeavour along with his inspiring leadership gave birth to a brand new Indian School of Chemistry in 1924.

(2) His contributions in the field of chemistry were widely acclaimed. He had written 107 papers in all branches of chemistry by 1920.

(3) He realised that advancement of India can happen only by economic advancement through development of new industries on scientific lines. He showed the way by investing his own money into forming Bengal Chemical and Pharmaceutical Works in 1893. This company culminated into the pioneer of chemical

industry in India. In 1902, it became a limited company and grew up under his guidance. He is considered as the father of Indian chemical industry.

11. Homi Jehangir Bhabha (1905 – 1966)

Homi Jehangir Bhabha, was an Indian nuclear physicist of Parsi-Zorastrian heritage who had a major role in the development of the Indian atomic energy programme and is considered to be the father of India's nuclear programme. After his death in 1966, the Atomic Energy Establishment was renamed as the Bhabha Atomic Research Centre in his honour.

Major contributions of Homi Jehangir Bhabha

(1) Cascade theory of cosmic radiations: He described how primary cosmic rays from outer space interact with the upper atmosphere and found that the electron showers were formed by the cascade production of gamma rays and positive and negative electron pairs.

(2) Proposed quantum theory regarding the behaviour of nuclear particles.

(3) Suggested vector theory of mesons.

(4) In 1945, he established the Tata Institute of Fundamental Research in Bombay.

(5) Established the Atomic Energy Commission of India in 1948.

(6) Served as the member of the Indian Cabinet's Scientific Advisory Committee and set up the Indian National Committee for Space Research with Vikram Sarabhai.

12. Subrahmanyam Chandrasekhar (1910 – 1995)

Subrahmanyan Chandrasekhar, was an Indian born American astrophysicist, and Nobel laureate in physics in 1983 along with William Alfred Fowler for their work in the theoretical structure and evolution of stars. Chandrasekhar served at the University of Chicago from 1937 until his death in 1995.

Major contributions of Subrahmanyan Chandrasekhar

(1) Studied stellar structure and stellar dynamics; proposed the theory of white dwarfs.

(2) Worked on hydrodynamic and hydromagnetic stability.

(3) Studied the equilibrium and the stability of ellipsoidal figures of equilibrium, and also general relativity.

(4) Studied on black holes and proposed Chandrasekhar limit - - the limit describes the maximum mass of a white dwarf star as approximately 1.44 times of solar mass, above which a star will ultimately collapse into a neutron star or a black hole (following a supernova).

(5) Worked on the theory of colliding gravitational waves.

13. Avul Pakir Jainulabdeen Abdul Kalam (1931-)

Avul Pakir Jainulabdeen Abdul Kalam was born 15th October 1931, in Rameswaram, Tamil Nadu, India. He was the eleventh President of India, serving from 2002 to 2007. He is known as the father of Indian missile technology. He has received honorary doctorates from as many as thirty universities. The Government of India has honoured him with the nation's highest civilian honours - - the Padma Bhushan in 1981; Padma Vibhushan in 1990; and the Bharat Ratna in 1997.

Major contributions of Abdul Kalam

(1) As the Project Director, he made significant contributions to the development of India's first indigenous Satellite Launch Vehicle (SLV-III).

(2) As the Chief Executive of Integrated Guided Missile Development Programme (IGMDP), he also played major part in developing many missiles of India including Agni and Prithvi.

(3) He was the Chief Scientific Advisor to Defence Minister and Secretary, Department of Defence Research and Development from 1992 to 1999. Pokhran-II nuclear tests were conducted during his tenure.

14. Vikram Sarabhai (1919 – 1971)

Vikram Ambalal Sarabhai was an Indian physicist. He was born on 12th August 1919 in the city of Ahmedabad in western India and is considered as the Father of the Indian space program. He was awarded Ph.D. by Cambridge university in 1947 for his thesis titled Cosmic Ray investigation in Tropical Latitudes.

Major contributions of Vikram Sarabhai

(1) Founded the Physical Research Laboratory (PRL) in Ahmedabad in 1947.

(2) He was the chairman of the atomic energy commission.

(3) Founder of rocket launching station, Thumba.

(4) Founder of rocket launching centre at Sri Haricotta.

(5) Founder of experimental satellite communication station at Ahmedabad.

(6) Conducted original researches in cosmic rays and contributed much to space research.

15. Enaackal Chandy George Sudarshan (1931 -)

E. C. G. Sudarshan was born on 16th September 1931, Pallam, in Kottayam district of Kerala, India, is a prominent physicist, author, and professor at the University of Texas at Austin.

Major contributions of Sudarshan

(1) He was the originator (with Robert Marshak) of the V-A theory of the weak force, which eventually paved the way for the electroweak theory.

(2) He developed a quantum representation of coherent light. His theorem proves the equivalence of classical wave optics to quantum optics. The theorem makes use of the Sudarshan-Glauber representation. This representation also predicts optical effects that are purely quantum, and cannot be explained classically.

(3) He was the first to propose the existence of tachyons, particles

that travel faster than light.

(4) Developed formalism called dynamical maps that is one of the most fundamental formalism to study the theory of open quantum system.

(5) In collaboration with Baidyanaith Misra, proposed the quantum Zeno effect.

(6) He worked on elementary particle physics, quantum optics, quantum information, quantum field theory, gauge field theories, classical mechanics and foundations of physics.

16. Meg Nad Saha (1893 – 1956)

Meg Nad Saha was born on 6th October 1893. He was educated at Calcutta and London and was Member of Parliament during 1952-56. As a member of Lok sabha, he fought for the development of heavy industries in the country (Joseph, 1982). The lasting memorial to him is the Saha Institute of Nuclear Physics at Kolkata.

Major contributions of Saha

(1) He studied on solar corona and invented an instrument to measure the weight and pressure of solar rays.

(2) He derived the famous equation which he called 'equation of the reaction - isobar for ionisation' which is known as Saha's Thermo-Ionisation Equation, or the Saha Equation. (Thermal ionisation -- when an element is heated to a very high temperature, the electrons in its atom get enough energy to break free from the atom). Meghnad Saha's ionisation equation opened the door to stellar astrophysics.

(3) Saha's equation is one of the basic tools for interpretation of the spectra of stars in astrophysics. By studying the spectra of various stars, one can find their temperature and from that, using Saha's equation, determine the ionisation state of the various elements in the star.

(4) He was associated with building several scientific institutions like the Physics Department in Allahabad University and the Institute

of Nuclear Physics in Calcutta.

(5) He founded the journal "Science and Culture" and was the editor until his death.

(6) Saha was the leading spirit in organising the scientific societies like the National Academy of Science, the Indian Physical Society, Indian Institute of Science and the Indian Association for the Cultivation of Science.

(7) He was also the chief architect of river planning in India. He prepared the original plan for the Damodar Valley Project.

17. Sivaram Krishna Chandrasekhar (1930 – 2004)

Sivaramakrishna Chandrasekhar was born on 6th August 1930 at Calcutta. He was a great material physicist who made outstanding contributions in the field of liquid crystals. Liquid crystals are the substances that have entered our daily lives since last thirty years; we see them in wristwatches, calculators and in many appliances. He was acknowledged world-wide, with his insightful and authoritative papers and his book titled "Liquid Crystals". He died on 8th March 2004.

Major contributions of Sivaramakrishna Chandrasekhar

(1) In 1977, he and his co-workers discovered a new type of liquid crystal made of a new type of molecule. These molecules had the shape of discs rather than the well studied rods. The discs exhibit columnar liquid crystals which had a two dimensionally periodic order.

(2) Discovered a new type of liquid crystals called discotic liquid crystals which are made up of octopus like molecules - the alkyl esters of hexahydroxy benzene, the maiden entry into this class was presented by Chandra along with his students Sadashiva and Suresh, who published the finding in the Indian physics journal "Pranama".

(3) His book 'Liquid Crystal' was popular amongst workers on that field and has been translated to Russian and Japanese.

(4) He started the Centre for Liquid Crystal Research.

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APPENDIX I

Concept Attainment Model – Lesson Plan

General Information

Name of the Teacher	:	Subject	:	Chemistry
Name of the School	:	Unit	:	Physical and chemical changes
Standard	: VIII	Lesson unit	:	Physical change
Division	:	Date	:	
Strength	:	Duration	:	45 minutes

Objectives

1. To help the pupil identify physical change
2. To help the pupil categorise physical change
3. To help the pupil cite examples for physical change
4. To help the pupil find out the properties of physical change
5. To help the pupil define physical change

Name of the concept: Physical change

Essential attributes:

1. Change in size, shape or the state of the substance
2. No new substance is formed
3. Temporary change

Non-essential attributes:

1. Colour of the substance
2. Amount of the substance
3. Temperature of the substance

	Positive examples:	Negative examples:
1.	Cutting of paper	Burning of wood
2.	Cutting of wood	Burning of paper
3.	Stretching of rubber band	Rusting of iron
4.	Melting of sulphur	Burning of sugar
5.	Stretching of iron into wires	Reaction between silver nitrate and sodium chloride
6.	Glowing of a filament	Burning of rubber band
7.	Breaking of glass	Burning of magnesium ribbon
8.	Melting of wax	Burning of candle

Rule to define the concept: Physical change is a temporary change which does not involve the formation of any new substance.

Orientation to the process	Response/Evaluation
Dear students today we are going to play a game, I have an idea in my mind. I am going to give you some examples in pairs labelled as 'Yes' and 'No.' The 'Yes' examples have something in common, you have to find out what is common (what are the common characteristics) in those examples.	Orientation to the process.
Phase I: Presentation of data and identification of the concept	
T: See the examples, now, I will present a pair, look I will write it on the black board; cutting of paper is a 'yes' example whereas burning of wood is a 'no' example. Now see the second set; cutting of wood is a 'yes' example and burning of paper is a 'no' example.	Teacher presents the first two pairs of labelled examples.
S: it may be related to breaking up of things.	Hypothesis I
T: but why did you say so?	
S: paper and wood are sliced in both the cases.	
T: now see the next pair, stretching of a rubber band is a 'yes' example and rusting of iron is a 'no' example.	Teacher presents the second set of labelled examples.
S: it is something like deformation of structure?	Hypothesis II
T: no.	
S: sir, give us the next pair.	
T: see the next pair, melting and cooling of sulphur is a 'yes' example while burning of sugar is a 'no' example.	Teacher presents the third set of labelled examples.
S: sir is it something related to states of substance.	Hypothesis III
T: why did you say so?	
S: in all the 'yes' examples no new substances is formed.	
T: yes, that is right.	
S: and in all 'no' examples some new substances are formed.	
T: OK, but was that the only observation.	
S: no, there are much more, size, shapes…	
S: the change seems to be temporary.	
T: exactly, come on just think…	
S: there is change in state for the examples given as 'yes'.	

T: yea, there you are, come on, now can you name that idea. S: No, sir. T: just try to state your inferences based on your observations. S: the idea in your mind might be a temporary change in which no new substances is formed. T: Very good; this type of changes are called physical changes, now can you define physical change based on your observations? S: physical changes are temporary changes in which no new substances are formed, but there may be change in size, shape and state.	Teacher names the correct concept. Pupil lists the essential attributes. Pupil states definition.
Phase II: Testing attainment of the concept	
T: I am going to give some pairs of examples. You have to label them as 'yes' or 'no.' Breaking of glass tumbler and burning of magnesium ribbon. S: the first one is a 'yes' example and the second a 'no' example. T: burning of candle and melting of wax. S: the first one is a 'no' example and the second one is a 'yes' example. T: very good; you are clear with the idea, now can you create some examples for the idea… S: stretching of iron into wires is a 'yes' example. S: melting of ice… S: boiling of water…	Students label the unlabelled examples. Students generate their own examples
Phase III: Analysis of the thinking strategy	
T: you people said that the concept in my mind was 'physical change,' but how did you reach that conclusion? S: sir, you first said you have something in your mind and challenged us to find it out and you started giving 'yes' and 'no' examples and we went on guessing. S: you started with two sets of examples cutting of	

paper and cutting of wood, as 'yes' examples whereas burning of paper and burning of wood as 'no' examples and there we got the idea of 'breaking up of things'.	Students describe thoughts.
S: sir, you said about stretching of rubber band	
S: yea, that's why I said about deformation…	
S: the right type of examples both 'yes' and 'no' and the hypotheses formulated helped us to reach the desired conclusion. The discussion with examples of melting and cooling of sulphur made our concept of physical change more clear.	Discuss the role of hypotheses
S: sir, it was a new experience for us, thank you.	
T: Oh! There the bell goes… bye students. I am taking leave…	
S: Thank you sir…	

APPENDIX II

Inquiry Training Model – Lesson Plan

General Information

Name of the Teacher	:	Subject	: Chemistry
Name of the School	:	Unit	: Acids and Bases
Standard	: VIII	Lesson unit	: Acids and carbonates
Division	:	Date	:
Strength	:	Duration	: 45 minutes

Objectives

1. To help the pupil formulate an explanation about the reaction between carbonates and acids
2. To help the pupil develop process skills such as observing, collecting data, developing hypothesis, experimenting, testing hypothesis and drawing inferences.
3. To help the pupil engage in strategies for creative enquiry through questions

Orientation to the process	Response/Evaluation
I am going to present a problem/puzzle/riddle/ magic trick before you. You have to find out a solution to the problem (try to explain the phenomenon that you are going to observe). You can raise questions to get it clarified but make sure that I could answer them in 'Yes' or 'No' only.	Teacher ensures that the pupil understood the rules of the problem
Phase I: Presenting a discrepant event or demonstrate the event	
T: Hey, see what all things are there with me? S: A glass beaker, egg, water… T: Ha! Let it be there… Last day I was in the kitchen to prepare some mango pickle I placed all the ingredients near the stove; I saw my wife rushing in with two eggs in her hand to prepare omelette, I asked her to go out and come after half an hour; we quarrelled over the matter, suddenly one of the egg rolled out of her hand and fell into a tumbler near me, I scolded her and was about to take a spoon to get it out of the liquid…but to our surprise… Oh! Let us see what happened, we have with us that liquid and the egg. Now watch it out carefully… S: Oh! The egg is rising to the top?	Pupil notes the discrepancy

Phase II: Data gathering - verification	
T: what are you asked to do? S: to ask questions and find out the reason behind the phenomena observed. T: how am I going to answer? S: in 'yes' or 'no'. S: is it hot water? T: no S: is it a rotten egg? T: no S: is it pure water? T: no S: is it concentrated solution of salt? T: no, come see what is going on… S: is it soap solution? T: no, why did you say so? S: is the bubble due to presence of soap? T: no, come on it's a good observation… S: is it due to formation of some gas? T: yes, you are correct.	
Phase III: Data gathering - experimentation	
S: is it the gas bubbling? S: yes S: a gas is being formed and it is seen as bubbles S: come see the bubbles sticking on the egg S: is it because of the bubbles… S: is the bubble sticking on to the egg? T: yes, very good observation, but how does it form? S: is there any reaction going on there? S: yes S: does the egg react with the solution? T: yes, but then what is the reaction? S: I have read that eggshell is made of carbonate; calcium carbonate. Am I right? T: yes.	Students explain in their own words

S: let me test the nature of the solution using a litmus paper S: yes, the blue litmus turns red… S: is the solution basic? S: no S: acids react with carbonates am I correct? T: yes S: but, why did the egg sink again? S: the gas on its surface might have escaped. Is it true? T: yes, but see it is rising again to the top S: the reaction is going on and the new gas molecules are sticking on to the surface of the egg and that makes it float. S: it is a marvellous piece of observation. S: is the gas formed carbon dioxide? T: yes, but how can you say that? S: acids react with carbonates to liberate carbon dioxide, so the gas formed might be carbon dioxide. S: let us test whether the gas will support combustion	
Phase IV: Organising, formulating explanation	
S: the egg on contact with acid reacts, because of the calcium carbonate present in the shell. The CO_2 formed sticks on to the shell making the egg less denser, due to increase in volume, causing it to rise to the top of the solution. S: on reaching to the surface of the solution, the gas escapes and the egg starts to sink because of density variation and the process goes on until all the $CaCO_3$ present in the shell gets used up. S: Acids react with carbonates liberating carbon dioxide. T. Yea, very good, now can you suggest more examples for this phenomenon, you can find it from our environment	

S: Concentrated floor-cleaning agents spoil the marble floor. S: Taj Mahal's white marble got faded because of acid rain.	
Phase V: Analysis of the inquiry process	
T: now let us recall what we have done to explain the reaction that puzzled you - what all questions and conclusions helped you to reach the answer? S: we first heard about your experience in the kitchen and saw you demonstrate it. T: what kind of questions did you ask? S: questions for which you answered 'yes' or 'no'. T: all right, did the questions help you in any way? S: yes, helped us to form some guesses. T: which question helped you to get on to the right track? S: the questions about the gas formed, about the solution, CO_2 gas formed on the surface of the shell were answered 'yes' and you made us probe deep into the problem. T: right, so at first you encountered with the problem, asked questions, collected information, tested your hypotheses andfinally arrived at the conclusion. A nice thing I noticed is that everyone participated in the inquiry process; it was really nice… shall I take leave… S: Thank you sir…	

APPENDIX III

A sample lesson plan in chemistry

(In the four column format incorporating Bloom's taxonomy)

I. General Information

Name of the teacher	:	Subject	: Chemistry
Name of the school	:	Unit	: Chemical equilibrium
Standard	: VIII	Lesson unit	: Irreversible and reversible reactions
Division	:	Date	:
Strength	:	Duration	: 45 minutes

II. Content Overview

Irreversible reaction - reversible reaction – forward reaction – backward reaction

III. Content Analysis

Symbol: (symbols to be added)

Terms:

1. Irreversible reaction
2. Reversible reaction
3. Forward reaction
4. Backward reaction

Facts:

1. Dilute sodium hydroxide reacts with dilute hydrochloric acid producing sodium chloride and water
2. Dilute hydrochloric acid reacts with zinc producing zinc sulphate and hydrogen
3. On heating, potassium chlorate gives potassium chloride
4. Potassium nitrate gives potassium nitrate on heating
5. When a glass rod dipped in ammonia is kept over hydrogen chloride white fumes are produced
6. Magnesium reacts with oxygen producing magnesium oxide
7. Phosphorous burns producing phosphorus pentoxide
8. Ammonium chloride decomposes into ammonia and hydrogen chloride
9. Ammonia reacts with hydrogen chloride producing ammonium chloride

Equations:

1. $NaOH + HCl \rightarrow NaCl + H_2O$
2. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
3. $2KClO_3 \rightarrow 2\,KCl + 3O_2$
4. $2KNO_3 \rightarrow 2KNO_2 + O_2$
5. $2Mg + O_2 \rightarrow 2\,MgO$
6. $4P + 5O_2 \rightarrow 2P_2O_5$
7. $NH_4Cl \rightarrow NH_3 + HCl$

Concepts:

1. In reversible reactions, the reactions do not cease but are in equilibrium
2. In reversible reactions, the reactants are converted into products and

products are converted into reactants

Definitions:

1. Forward reaction: the reaction in which the reactants are converted into products is called a forward reaction
2. Backward reaction: the reaction in which the products are converted into reactants is called a backward reaction
3. Reversible reaction: the reaction in which the reactants are converted into products and the products are converted into reactants is called a reversible reaction
4. Irreversible reaction: the reaction in which the reactants are completely converted into products and the reverse process is not possible is called a irreversible reaction

IV. Statements of instructional objectives

1. The pupil acquires knowledge of the above mentioned symbols, terms, facts and equations
2. The pupil develops understanding of the above mentioned symbol, terms, facts equations concepts and definitions
3. The pupil applies their understanding in new and unfamiliar situations
4. The pupil develops skill in observation through demonstrations
5. The pupil develops interest in doing various experiments
6. The pupil develops scientific attitude such as open mindedness and intellectual honesty
7. The pupil develops scientific appreciation of the contributions of science to life and society

V. Previous knowledge

1. The pupil is familiar with certain chemical reactions.
2. The pupil knows how to write balanced chemical equations

VI. Teaching aids

a) Glass wares/apparatus

1.	Beakers (100 ml)	5	2.	Test tubes (15 ml)	2
3.	Spirit lamp	1	4.	Glass rod	1

b) Chemicals

1.	Sodium hydroxide	10 ml	2.	Litmus paper (red)	1
3.	Phenolphthalein	2 ml	4.	Dilute hydrochloric acid	10 ml
5.	Ammonium chloride	10 g	6.	Magnesium	2 g
7.	Water	500 ml			

c) Improvised aids

Nil

VII. Body of the lesson plan

Content	Specification	Learning experience	Evaluation
Preparation Sodium hydroxide solution is alkaline which turns red litmus to blue	recalls	What is meant by a chemical reaction? 10 ml of dilute sodium hydroxide solution is taken in a test tube, litmus paper is dipped in the solution. What is the nature of the solution?	
Presentation Dilute sodium hydroxide reacts with dilute hydrochloric acid producing sodium chloride and water	identifies infers	Two drops of phenolphthalein are added, solution turns pink. 10 ml of dilute hydrochloric acid is added. Test tube is shaken. What happened to the colour of the solution when hydrochloric acid is added? $NaOH + HCl \rightarrow NaCl + H_2O$ (BBW)	What is the reason for the decolourisation of the solution?
Magnesium reacts with oxygen producing magnesium oxide	recalls	What is the chemical name of the ash formed when magnesium ribbon is burnt? $2Mg + O_2 \rightarrow 2\,MgO$ (BBW)	What is the product formed when magnesium is burnt?
The reaction in which the reactants are converted into products is called a forward reaction	suggests defines	What may be the name given to the reaction in which the reactants are converted into products? Forward reaction (BBW)	What is meant by forward reaction?

Ammonium chloride decomposes into ammonia and hydrogen chloride	identifies	5g of ammonium chloride is taken in a test tube. Moist red litmus paper is placed at the mouth of the test tube. Test tube is heated. What may be the reason for the red litmus paper to turn to blue? Which alkali in the test tube makes red litmus paper turn blue?	What are the products formed when ammonium chloride is heated?
	identifies	Ammonia.	
		What are the products in this reaction?	
	predicts	Ammonia and hydrogen chloride	
	translates	$NH_4Cl \rightarrow NH_3 + HCl$ (BBW)	
Ammonia reacts with hydrogen chloride producing ammonium chloride		Test tube is heated further. What is the substance deposited inside of the test tube?	What is the product formed when ammonia is treated with hydrochloric acid?
	predicts	Ammonium chloride (BBW)	
		$NH_3 + HCl \rightarrow NH_4Cl$ (BBW)	
		What is the name given to the reaction in which products are converted into reactants?	
The reaction in which the products are converted into reactants is called a backward reaction	suggests defines	Backward reaction (BBW)	What is meant by backward reaction?
The reaction in which the reactants are converted into products and the products are converted into reactants is called a reversible reaction	suggests defines	What is the name given to the reaction containing forward reaction and backward reaction? Reversible reaction (BBW)	What is meant by reversible reaction?

In the forward reaction ammonium chloride gives ammonia and hydrogen chloride and in the backward reaction ammonia and hydrogen chloride combine to form ammonium chloride	translates compares contrasts	How can a reversible reaction be represented? $NH_3 + HCl \leftrightharpoons NH_4Cl$ (BBW) How is this reaction different from the reaction between sodium hydroxide and hydrochloric acid?	How is the reversible reaction of ammonium chloride represented? What is the difference between the reaction of ammonium chloride and the reaction of sodium hydroxide and hydrochloric acid?
The reaction in which the reactants are completely converted into products and the reverse process is not possible is called a irreversible reaction	suggests defines	Two reactions are there, for ammonium chloride while there is only one for sodium hydroxide and hydrochloric acidWhich is the backward reaction in the case of sodium hydroxide and hydrochloric acid?What is the name given to the reaction containing only forward reaction? Irreversible reaction (BBW)	What is meant by irreversible reaction?
Application The formation of ammonia from hydrogen and nitrogen is a reversible reaction	cites example	How ammonia is formed? Represent the reaction. $N_2 + 3H_2 \leftrightharpoons 2NH_3$	Cite an example for a reversible reaction?

Review

1. What is the product formed when magnesium is burnt?
2. What is meant by forward reaction?
3. What are the products formed when ammonium chloride is heated?
4. What is the product formed when ammonia is treated with hydrochloric acid?
5. What is meant by backward reaction?
6. What is meant by reversible reaction?
7. How is the reversible reaction of ammonium chloride represented?
8. What is the difference between the reaction of ammonium chloride and the reaction of sodium hydroxide and hydrochloric acid?
9. What is meant by irreversible reaction?

Assignment

1. Prepare a list of three reactions that are examples of reversible reaction.

APPENDIX IV

A Sample Lesson Plan in Chemistry

(In constructivist model incorporating new taxonamy of science education)

1. **General Information**

Name of the Teacher	:	Subject	: Chemistry
Name of the School	:	Unit	: Water
Standard	: VIII	Lesson Unit	: Hardness of water
Division	:	Date	:
Strength	:	Duration	: 45 minutes

II. Content Overview

(Here a broad out line of the content should be given)

Hard water- soft water - reasons for hardness of water- temporary hardness- permenent hardness- how to remove hardness.

III. Content Analysis

(Here analysis of the content area in terms of symbols, terms, facts, concepts, definitions, formulae, equation, conventions, hypotheses, laws, principles and processes should be given.)

Terms

1. Hard water
2. Soft water
3. Temporary hardness
4. Permanent hardness

Facts

1. Soap does not form lather with water in which calcium chloride is dissolved.
2. Soap does not form lather with water in which magnesium chloride is dissolved.
3. Soap does not form lather with water in which calcium bicarbonate is dissolved.
4. Soap forms lather with water containing calcium bicarbonate when it is heated .
5. Water containing calcium chloride after treatment with sodium carbonate forms lather with soap.
6. Water containing magnesium chloride after treatment with sodium carbonate forms lather with soap.

Concepts

1. Hard water doesnot form lather with soap due to the presence of dissolved salts of magnesium and calcium.
2. Soft water easily forms lather with soap.

3. Hardness of water can be removed by removing the dissolved salts of calcium and magnesium, either by heating or adding sodium carbonate/ chemicals.

Definitions

1. Water that does not easily form lather with soap due to the presence of dissolved salts of calcium or magnesium is called hard water.
2. Water that easily forms lather with soap is called soft water.
3. Hardness of water caused by dissolved bicarbonates that can be removed by heating is called temporary hardness.
4. Hardness of water caused by dissolved sulphates and or chlorides and can only be removed by adding sodium carbonate (chemicals) is called permanent hardness.

Equations

1. $Ca(HCO_3)_2 \xrightarrow{heat} CaCO_3 + H_2O + CO_2\uparrow$
2. $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2\,NaCl$
3. $Mg\,SO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$

IV. Learning Objectives

1. Knowledge Domain

The pupil develops knowledge and understanding about the above mentioned terms , facts, concepts, etc.

Specific Objectives

a. Identifies the causes of hardness of water.
b. Finds reasons for not using sea water for domestic purposes.
c. Describes the reactions while heating hard water or when treated with sodium carbonate.

2. Process Domain

The pupil acquires process skills required to develop knowledge and understanding of above mentioned concepts, definitions, etc.

Specific Objectives

a. Does experiments related to the nature of water
b. Observes various experiments carefully
c. Communicates ideas related to causes of hardness of water, with peers.
d. Develops operational definition for hardness of water
e. Makes inferences related to the topic hardness of water

3. Application Domain

The pupil applies the aquired knowledge and skills in new and unfamiliar situations.

Specific Objectives

a. Finds instances from daily life where the hardness of water is to be considered.

b. Selects appropriate technique to remove hardness of a sample of water.

4. Creativity Domain

The pupil develops creative abilities related to the topic.

Specific Objectives

a. Designs devices to remove hardness of water for domestic purposes.

b. Advances ideas to prepare soaps that can be used even in hard water.

5. Attitudinal Doman

The pupil develops scientific attitudes and values by learning the topic.

Specific Objectives

a. Shows interest in doing experiments related to hardness of water.

b. Shows honesty in recording observations during experiments.

V. Strategies

1. Experiments
2. Group discussion
3. Demonstration

VI. Pre- requisites

1. The pupil knows that there are soluble and insoluble salts of elements such as magnesium and calcium
2. The pupil knows a number of salts that are dissolved in the water obtained from various sources.

VII. Misconceptions

Pupil may think that the presence of sodium chloride is the only reason for not using sea water for domestic purposes.

VIII. Learning Materials

a) Glass wares/Apparatus:	Boiling tube	6
	10 ml test tube	18
	Spirit lamp	6
b) Consumables :	Water	1 litre
	Calcium chloride	30 g
	Magnesium sulphate	30 g
	Calcium bicarbonate	30 g
	Sodium carbonate	30 g
	Soap pieces	30 g
c) Improvised aids:	Nil	

IX. Precautions/ First Aid Do not taste the chemicals

X. Classroom Transaction

Process/ Activity	Response/ Evaluation
1. Orientation/ Organisation (3 minutes) Teacher encourages the students to discuss about the nature of water that is used for domestic purposes and divides the class into six groups (The number of students in a group can be conveniently fixed to facilitate group activities. Names may be given to each group and leaders may be selected in each group by members of the group) No. of groups - 6 No. of sessions- 5	(The appropriate-ness of grouping)
2. Session 1 (10 minutes) Each group is asked to dissolve a little /2 g calcium chloride and a little /2 g magnesium sulphate in water taken in two different test tubes and to shake it with the given soap pieces. They are also asked to shake soap pieces with water taken in another test tube and compare the findings and to write their inferences after discussing the findings in their groups. **Consolidation of idea** When salts of calcium or magnesium is dissolved in water, it will not form lather with soap. Such water is called hard water. In pure water soap forms lather easily and is called soft water.	(Here the perfor-mence of students in each group should be recerved. The effectiveness of the selected activity in constructing concept to be assessed and recorded . This is to be done for each activity in the class)
3. Session 2 (5 minutes) Students are asked to make operational definitions for hardness of water by discussing in their groups. **Consolidation of idea** Water that doesnot form lather easily with soap , due to the presence of dissolved salts of calcium or magnesium is called hard water. water that easily form lather with soap is called soft water.	
4. Session 3 (10 minutes) Each group is asked to dissolve calcium bicarbonate in water and to test its lather formation with soap. They are asked to heat the water containing calcium chloride, magnesium sulphate and calcium bicarbonate, and then to test the lather formation with soap. They are asked to write their inferences after discussing the findings within their groups.	

Process/ Activity	Response/ Evaluation

Consolidation of idea

Hardness of water caused by bicarbonates can be removed by heating and such hardness is called temporery hardness.

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2\uparrow$

5. Session 4 (10 minutes)

Each group is asked to add sodium carbonate to water containing calcium chloride and water containing magnesium sulphate and to test the lather formation with soap. They are asked to discuss the findings and to write down their inferences.

Consolidation of idea

Hardness of water caused by sulphates and chlorides of calcium or megnesium can be removed by adding sodium carbonate. Such hardness is called permanent hardness.

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2\,NaCl$

$MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$

6. Session 5 (5 minutes)

Students are asked to make definitions for temporary hardness and permanent hardness by discussing in their groups.

Consolidation of idea

Hardness of water caused by dissolved bicarbonates and can be removed by heating is called temporary hardness. Hardness of water caused by dissolved sulphates and or chlorides and can only be removed by adding sodium carbonate/chemicals is called permanent hardness.

XI. Follow up Activities

a) Written assignments

1. What is hard water?
2. What is soft water?
3. Suggest a method to remove hardness of water?
4. What are the causes of hardness of water?

b) Activity assignment

Collect samples of water from two different sources in your locality and compare the lather formation with soap.

APPENDIX V

A Sample Lesson Plan in Physics

(In the constructivist format incorporating new taxonomy of science education)

1. **General Information**

Name of the Teacher	:	Subject	: Physics
Name of the School	:	Unit	: Current electricity
Standard	: VIII	Lesson Unit	: Rheostat
Division	:	Date	:
Strength	:	Duration	: 45 minutes

II. Content Overview

Rheostat – parts – function – working of

III. Content Analysis

Symbol

(symbolic representation of rheostat)

Terms

1. Rheostat
2. Sliding contact

Facts

1. Resistance of a small pencil is less than that of a lengthier one of the same kind
2. Resistance of a 10 meter metallic wire is greater than that of a 5 meter wire

Concepts

1. Rheostat is a device used to change the resistance in an electric circuit
2. Rheostat can be used in an electric circuit to control the intensity of electric current

IV. Learning Objectives

1. Knowledge Domain

The pupil develops knowledge and understanding about the above mentioned symbols, terms, facts and concepts.

Specific Objectives

a. Recognises the role of resistance in the conduction of electric current
b. Identifies the parts of a rheostat
c. Describes the function of different parts of rheostat
d. Gives reason for the change in resistance of a conductor when the sliding contact of the rheostat is moved
e. Identifies the change in brightness of the bulb and reading of the ammeter when the resistance is changed

2. Process Domain

The pupil acquires process skills required to develop the knowledge and understanding of the above mentioned facts and concepts

Specific Objectives

a. Examines and experiments with rheostat
b. Observes the experiments carefully
c. Communicates the ideas related to rheostat with peers
d. Infers that the movement of sliding contact is the reason for change in resistance
e. Predicts the brightness of bulb when the sliding contact is moved on either side

3. Application Domain

The pupil applies the aquired knowledge and skills in new and unfamiliar situations.

Specific Objectives

a. Cites examples for devices where rheostats are used
b. Distinguishes the variation in ammeter reading when the sliding contact is adjusted

4. Creativity Domain

The pupil develops creative abilities related to the topic.

Specific Objectives

a. Designs circuits which involve the use of rheostat
b. Advances ideas regarding the use of rheostat in electrical and electronic circuits

5. Attitudinal Doman

The pupil develops scientific attitudes and values by learning the topic.

Specific Objectives

a. Collects more information regarding rheostats and their importance in current electricity
b. Shows honesty in recording observations during experiments

V. Strategies

1. Experiments
2. Group discussion

VI. Pre- requisites

1. The pupil knows the concept of resistance of a conductor
2. The pupil knows that the resistance of a conductor depends on its length.

VII. Misconceptions

The resistance offered by a rheostat depends on the size of the rheostat

VIII. Learning Materials

a. Glass wares/apparatus	Rheostat 100 ohm	- 5
	1.5 volt cell	- 10
	1.5 volt bulb	- 5
	Ammeters	- 5
	Key/switch	- 5
	Pencils	- 5
b. Consumables	Nil	

c. Improvised aids

A chart showing the circuit diagram involving ammeter, bulb, key and a cross-section of a pencil

IX. Precautions/ First Aid

Use ammeters of suitable range to show deflections for cells connected

X. Classroom Transaction

Process/ Activity	Response/ Evaluation
1 Orientation/Organisation (5 minutes) Students, today we will do some interesting experiments with equipment.The teacher divides the students into five groups No. of groups: 5 No. of sessions: 4	(The appropriate-ness of grouping)
2. Session 1 (15 minutes) Each group is provided with a bulb, a switch, an ammeter; a lead pencil cut open into two halves and connecting wires (shown on chart).(Draw the circuit diagram with the components given above) Each group observes the brightness of the bulb and the ammeter reading by sliding the arrow headed wire over the thin graphite rod in the pencil and records their observations in the science diary. The students are asked to find out answers for the following questions by discussing in their groups. What relationship did you observe on the brightness of bulb and movement of arrow headed wire over the lead of the pencil? Is there any relation between the reading of ammeter and movement of arrow headed wire over the lead of the pencil?	(Here the perfor-mence of students in each group should be recerved. The ef-fectiveness of the se-lected activity in constructing con-cept to be assessed and recorded . This is to be done for each activity in the class)

Process/ Activity	Response/ Evaluation
Idea to be consolidated Resistance of a conductor can be varied and the strength of the electric current can be controlled by varying resistance. **3. Session 2** (10 minutes) The students get familiarised with the device rheostat. Each group observes the parts of the rheostat provided to them and notes down the details. Teacher provides them with the symbolic representation of rheostat. **Idea to be consolidated** Rheostat is a device which consists of a cylindrical porcelain hollow tube over which a metallic wire is wound. It has a sliding contact which helps to vary the length of the metallic wire to be included in the circuit. **4. Session 3** (10 minutes) Students in groups repeat the experiment done in the first session by replacing the lead pencil with a rheostat. Each group notes down the brightness of the bulb and ammeter reading by adjusting the sliding contact of the rheostat. The students are asked to find out answers for the following questions by discussing in their groupsWhat relationship did you observe on the brightness of bulb and movement of sliding contact?Is there any relation between the reading of ammeter and movement of sliding contact? **Idea to be consolidated** Varying the length of the conductor can help in increasing or decreasing the resistance of a rheostat and thereby control the electric current in a circuit. **5. Session 4** (5 minutes) Each group is asked to discuss about the impact of increasing the number of turns on the rheostat (The appropriateness of grouping)(Here the performance of students in each group should be	

Process/ Activity	Response/ Evaluation
recorded. The effectiveness of the selected activity in constructing the concept to be assessed and recorded. This is to be done for each session of the class.)	

XI Follow up activities

1. **Written assignments**

a. What is the function of a rheostat in a circuit?

b. What similarities could you find while experimenting with pencil and rheostat?

2. **Activity assignment**

   Improvise a pencil rheostat

Appendix VI
A sample micro-lesson on skills of probing questions

Name of Student - teacher	:	Subject	: Chemistry
Name of School	:	Unit	: Acids and bases
Standard	: VIII	Lesson Unit	: Properties of acids
Division	:	Date	:
Strength	: 5-10	Duration	: 6 minutes

Classroom Transaction

Teacher : What is the taste of lemon juice?
Student : Lemon juice has sour taste.
Teacher : What is the reason for the sour taste ? (Seeking further information)
Student : Presence of acid
Teacher : Good. Can you name any other substance that contains acid that we use at home ? (Seeking further information)
Student : Vinegar, curd.........
Teacher : OK, can you name the acids present in them ? (Seeking further information)
Student : Acetic acid, citric acid.................
Teacher : Can you name some strong acids used in the laboratory ? (Refocusing)
Student : Sulphuric acid, hydrochloric acid, nitric acid..........
Teacher : What is the effect of acids on metals ? (Seeking further information)
Student : No response
Teacher : Can anyone answer me ? (Redirecting)
Student : No response
Teacher : How will you prepare hydrogen gas ? (Prompting)
Student : We get hydrogen gas when dilute hydrochloric acid reacts with zinc foil.
Teacher : Good. what happen when dilute sulphuric acid reacts with magnesium ? (Refocusing)
Student : We get hydrogen
Teacher : What is common in these two reactions ? (Seeking further information)
Student : Hydrogen gas
Teacher : What inference can we draw from this ? (Increasing critical awareness)
Student : No response.
Teacher : Can anybody answer me ? (Redirecting)
Student : Metals react with acids to give hydrogen gas
Teacher : Very good, acids react with metals to liberate hydrogen gas

AUTHOR INDEX

SUBJECT INDEX

About the Authors

Fr. K. M. Rajan is a lecturer (Selection Grade) in physical science at St. Joseph's Training College, Mannanam, Kottayam since 1983. He was a research fellow with the California Educational Research Cooperative (CERC), University of California, Riverside, U. S. A. during 1990-1993

He received his B.Sc. degree (1978) from the University of Kerala, his M.Sc. degree (1980) from Jabalpur University, his B.Ed. Degree (1981 - First Rank) and M.Ed. degree (1983) from Calicut University, his Ph.D. degree from the University of California, U.S.A. At present, he is a research guide in Education at the School of Pedagogical Sciences, M.G. University, Kottayam.

He is a member of the American Educational Research Association (AERA) and has attended American Educational Research Association (AERA) meetings at Chicago (1991) and San Francisco (1992). He is a life member of Council for Teacher Education (CTE), All India Association for Educational Research (AIAER), International Association of Educators for World Peace (IAEWP) and a member of All Kerala Training College Teachers' Association (AKTCTA). He has published four books and eight research articles.

B. S. Sindhu is a Lecturer in Physical Science at Patriarch Ignatius Zakka I Training College, Malecruz, Ernakulam, and has twelve years of experience as a teacher educator.

She received her Masters Degree in Chemistry (1994) and Education (1996) from the University of Kerala and secured Masters Degree in Sociology (2004) from Madurai Kamaraj University. She has qualified UGC-NET in Education (1999). She is a research scholar in Education, at the School of Pedagogical Sciences, Mahatma Gandhi University.

She is a member of Council for Teacher Education (CTE). She has attended several conferences, seminars, workshops, and courses organised by UGC, Kerala and Mahatma Gandhi Universities.

Josen George is a Lecturer in Physical Science at Avila College of Education, Edacochin, Cochin.

He received his B.Sc. Chemistry in 1988, M.Sc. Chemistry in 1990, M.A. Sociology in 1995 (3rd Rank), B.Ed. in 2000, and M.Ed. in 2002 (1st Rank) from Mahatma Gandhi University, Kottayam. He has qualified UGC-NET in Education in 2003. He has submitted doctoral thesis in Education in 2008 at Mahatma Gandhi University.

He has attended conferences, seminars, workshops, and courses organised by UGC, SCERT, and Mahatma Gandhi University. He has participated and presented papers at national seminars and published papers in Journals of Education.

Sibu G. Netto is a Lecturer in the Postgraduate Department of Mar Severios College of Teacher Education, Mallappally, Chengaroor since 2007. He has five years of teaching experience as a Lecturer in Physical Science at under graduate level.

He received his Bachelors Degree in Chemistry (1997), Education (1999), and Masters Degree in Chemistry (2001) from the University of Kerala, Thiruvananthapuram He secured second rank for Masters Degree in Education in 2002 from Mahatma Gandhi University, Kottayam. He has submitted doctoral thesis in Education in 2008 at Mahatma Gandhi University.

He has attended conferences, seminars, workshops, and courses organised by UGC, SCERT, and Mahatma Gandhi University. He has participated and presented papers at state and national seminars.

Sajan R. K. is a Lecturer in Physical Science at Sree Narayana College of Education, Muvattupuzha, Ernakulam since 2003. He has also worked as Lecturer in Physics at higher secondary schools.

He received his B.Sc. Physics in 1998, M.Sc. Physics in 2000, B.Ed. in 2001 from the University of Kerala and M.Ed. in Science Education from Annamalai University, Chidambaram securing second rank in 2003. He has qualified UGC-NET in Education in 2003.

He is a member of Council for Teacher Education (CTE). He has attended several conferences, seminars, workshops, and courses organised by UGC, Kerala and Mahatma Gandhi Universities. He has participated and presented papers at national and international seminars.