Pedagogy of Teaching Physical Science
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B.Ed. (2nd Semester)

Study Materials Prepared

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Unit 1: Foundation of Science Teaching

1.1 Aims and objectives of Science teaching

For carrying out any activity it is important to know its purpose. If the purpose is clear, the activity will be carried out effectively. If one knows clearly what is to be achieved, the planning will be done accordingly and the work will be carried out properly. In the same way in education the identification of goals, aims and objectives is a very important activity. Aims and objectives of science education and science teaching have undergone many changes because the goals of education are also changes in the society.

According to E.S. Bloom, "Educational objectives are not only the goals towards which curriculum is shaped and towards which instruction is guided, but they are also the goals that provide the detailed specification for the construction and use of education techniques."

According to E.J. Frust, "An education objective may be defined as a desired change in behaviour in a person that we are trying to bring about through education."

Need of Educational Objectives

The objectives should be determined before the teaching of science. Prior to fixing any objectives the following issues should be kept in mind:

- The objectives should be set according to the needs and interests of the students.
- The objectives should be in accordance with the intellectual level and status of the students.
- The objectives should be related to the entire syllabus of the class.
- The objectives should help in achieving the aims of democratic education.
- The objectives should help in bringing about the desired changes in the behaviour of the learner.
- The objectives should be helpful in evaluation of the progress of the learner.
- The objectives should be helpful in selection and proper utilisation of the teaching-aids.
- The objectives should work as a guide in helping students to gain real, true and practical knowledge.

- The objectives should be affordable, within the achievement level and in accordance with our means and requisites.

Aims of Teaching Science

They serve to suggest general direction in which our science courses may be steered. Aims of teaching science are given below:

- To provide practical knowledge and latest knowledge of the subject matter.
- To provide fundamental skills and processes for the proper understanding of subject matter.
- To give students broad genuine appreciation of what developments of science mean to modern life.
- To satisfy natural interests.
- To contribute specific ideals like concepts accuracy, truthfulness, honesty, open mindedness, ordered system, neatness etc.
- To stimulate spirit of investigation and invention.
- To educate the students about the application of science in daily life and society.
- To develop capacity to solve problems.
- To develop economic efficiency.
- To develop scientific appreciation and scientific temper among the students.
- To develop in students the observation capacity.

In addition to these some other aims are:

- Aims of achieving the practical value of science.
- Social aims.
- Cultural aims.
- Discipline-related aims.
- Aims related to intellectual development.
- Character building aims.
- Aims related to earning livelihood and vocational aims.
- Aims of proper utilization of vocation and drawing pleasure out from it.
- Aims of providing guidance in study of other subject and further studies.

Differences between Aims and Objectives

Generally the terms aims and objectives are used synonymously but actually the two terms are different. Aim is general declaration of intent that gives direction to the teaching programme. Objectives are small that is helpful in achieving a specific aim about the desired behaviour changes in the students.

A few differences between aims and objectives are given in the following table:

Sl No	Aims	Objectives
i	Aim is a general declaration of intention which gives directions to a teaching programme.	Objective is a particular point in that direction.

ii	Aim is the answer to the question of why a subject is taught.	It is an answer to the question of what will be achieved after the teaching of a topic.
iii	They are indefinite, vague and unclear.	They are generally definite and clear.
iv	Schools, society and nations are responsible for their fulfillment.	Mostly the teacher is responsible for their fulfillment.
V	Aims are close to the ideals which cannot be fully achieved.	They can be fully achieved.
Vi	A lot of time is required for their achievement.	Time taken is not much. The achievement of objectives can be verified along with the teaching of the lesson or after the completion of the lesson.

Bases for the formulation of objectives

Formulation of objectives should be based on a solid philosophical, psychological, sociological and scientific base. The utility, appropriateness, practicability are the major concerns. The sources are:

- The needs and capabilities of the learner.
- The needs of the society.
- The nature of the subject matter.
- The nature of the educational systems.
- The feasibility/constraints

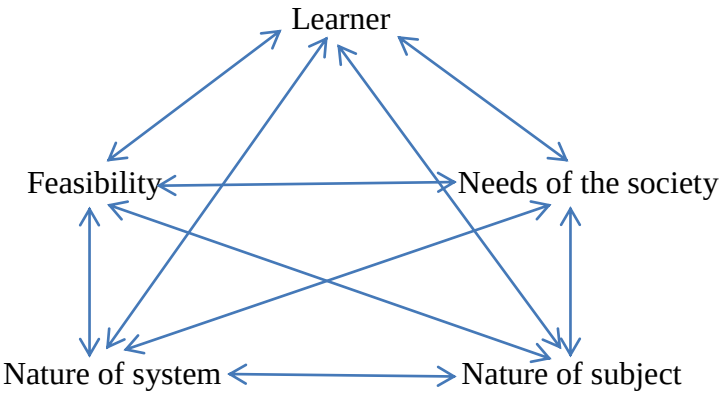

Figure 1.1 Needs for the formulation of objectives

Criteria for the Selection Objectives

The objectives should be formulated in the light of the needs of the society, nature of the subject and the nature of the pupils. In selecting objectives, various criteria may be used. Generally accepted criteria for a statement of a good objective are that they should be in line

with the aims of education, specific in term of means, ends and timeframe, useful for the student and feasible for application.

Thurber and Collette have suggested the criteria for selecting objectives as:

- **Usefulness**: The desired learning should have value in the lives of the students.
- **Timeline**: Learning should be concerned with familiar material with absolute desires and ideas.
- **Fitness**: The learning should fit into sequence learning towards broader objectives.
- **Appropriateness**: The extent of expected learning should coincide with the maturity and background of the pupils concerned.
- **Practicability**: Experiences needed for the development of the learning should be possible.

Objectives of Science Teaching

The objective of teaching science to the students is to develop scientific attitudes and skills of the students. The students can patiently learn to remain disciplined through the medium of science. The modern education is known for the all round development of the child as it is 'child-centred'. The objective of learning science also preaches the all round development of the child. In this manner, the students can progress physically, mentally and economically. Side by side he/she can become a scientist and earn his / her livelihood and also contribute in the production and development of the nation. In this manner by the study of science, the students will become self-reliant and also develop the attribute of dignity of labour.

The objectives of teaching science should have the following qualities:

- They should be based on psychological principles.
- They should resemble the ideals of democratic education.
- They should be able to bring about anticipated changes.
- They should be useful.
- They should be in agreement with the time and circumstances.

Types of Objectives

The objectives are of three types:

General objectives: These objectives are general in the form of **'Science as a subject'**.

Specific objectives: These objectives pertain to a particular chapter in a particular time period. These can further be divided into the following categories:

- Knowledge
- Understanding
- Application
- Skill

Expected behavioural objectives: These objectives indicate the expected behavioural changes that can occur in the students. Will the students be able to define a draw an outline of the fact ? Will they be able to restrain a theory and divide it into paragraphs and show cleverness?

Bloom's Taxonomy of Education Objectives

Instructional objectives are divided it into three major domains:

- **Cognitive domain** – knowledge and intellectual abilities
- **Affective domain** – objectives of interest and feeling

- **Psychomotor domain** – development of skills

Cognitive Domain: It helps the children to
- Understand the need for adequate food and that proper nutrition is essential for physical and mental development, health and happiness.
- Become aware of the foods available in the locality and need to produce more food.
- Become aware of the ways in which food can be prepared and made attractive, tasty and nutritious in eating.

Affective Domain (Attitude): It helps the children to
- Take interest in selecting, and in liking to eat different groups of good.
- Feel the necessity of producing more food and take interest in kitchen gardening.
- Take interest in finding out whats kinds of food are available in the locality.
- Become convinced of avoiding waste of food at all levels.

Psychomotor Domain (skill): It helps the children to
- Select and eat proper combination of food.
- Do not eat without washing hands, but wash hands before and after eating and develop similar hygienic food practices.
- Participate in food production at home and in school.
- Explain the kinds of food available in the locality.

Cognitive Domain

Cognitive objectives were further classified into six categories–

(i) Knowledge (ii) Comprehension (iii) Application (iv) Analysis (v) Synthesis and (vi) Evaluation.

(i) Knowledge

Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is the bringing to mind of the appropriate information. Knowledge represents lowest level of learning outcomes in the cognitive domain.

Example : Knows common terms, specific facts knows methods and procedures, knows basic concepts, knows principles, theories and structure, information, terminology, dates, events, classification etc.

Learning Outcomes
- Recalls, terms, facts, concept, principles and processes related to Science.
- Recognises various terms, facts, concepts and principles of Science.

Behavioural Terms: Defined, describe, identify, label, list, match, name, outline, reproduce, select, state, recall, recognise, classify etc.

(ii) Comprehension

Comprehension is defined as the ability to grasp the meaning of the material. This may be shown by translating material from one form to another (words to numbers), by interpreting

material (explaining or summarising) and by establishing outcomes go one step beyond the simple remembering of material and represent the lowest level of understanding.

Example: Understands facts and principles, interprets verbal material, interprets chats and graphs, translates verbal material to mathematical formula, estimates future consequences implied in date, justify procedures and methods.

Learning Outcomes

- Translates verbal statements into symbolic equation and vice versa.
- Gives illustration of principles of science.
- Sees relationship between cause and effect of scientific phenomena.
- Compares various methods, concepts, principles etc.
- Detects errors in given statements, circuit, arrangements etc. and rectifies the same.
- Classifies as per criteria, the objects, etc.
- Gives explanation of scientific phenomena, principles, concepts, etc.
- Reads and interprets graph.
- Solves numerical problems involving scientific concepts etc.
- Recognise the significance and limitations of scientific principles.

Behavioural Terms: Convert, explain, extend, generalise, give example, infer, paraphrase, predict, rewrite, summarise etc.

(iii) Application

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws and theories. Learning outcome in this area require a higher level of understanding than those under comprehension.

Problem presented

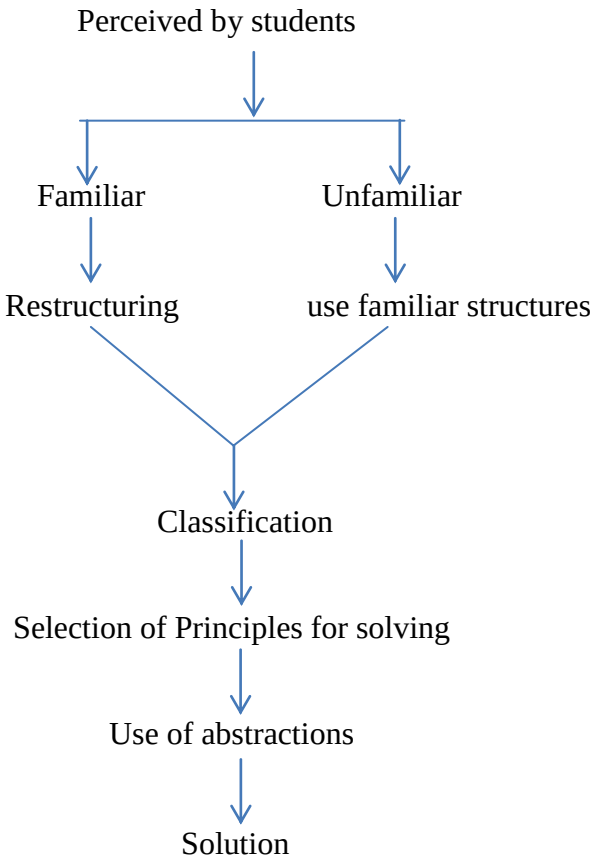

Figure 1.2 Various steps involved in Application

Example: Applies concepts and principles to new situations, applies laws and theories to practical situations, solves mathematical problems, constructs charts and graphs an demonstrates correct usage of a method or procedure.

Learning Outcomes

- Analysis the unfamiliar situations, statements, observations, evidence, etc.
- Formulates hypotheses based on data, observations etc.
- Devices new experiments for verifications of the hypotheses and for known laws and principle etc.
- Establishes relationship between cause and effect, the known and unknown.
- Selects the principles relevant to a phenomena.
- Draws inferences and conclusions from the given data or observed phenomena.
- Makes predictions on the basis of data, evidence etc.
- Judges the relevance, adequacy and consistency in statements, data, evidences etc.

Behavioural Terms: Change, compute, demonstrate, solve, discover, manipulate, modify, operate, predict, prepare, relate, show, use etc.

(iv) Analysis

Analysis refers to the ability to breakdown material into its component parts so that its organizational structure may be understood. This may include the identification of the parts, analysis of the relationship between parts, and recognition of the organising principle involved. Learning outcome here represent higher level of intellectual skills than comprehension and application because they require an understanding of both the content and the structural form of the material.

Example: Recognise unstated assumptions, recognises logical fallacies in reasoning, distinguishes between facts and inferences, evaluates the relevancy of data, and analysis the organizational structure of a work (arts, music, writing, project report) .

Behavioural Terms: Breakdown diagrams, differentiate, discriminate, distinguish, identify, illustrate, infer, outline, point out, relate, select, separate, subdivide etc.

(iv) Synthesis

Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operation (research proposal) or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviour, with major emphasis on the formulation of new pattern or structures.

Examples : Writes a well-organised theme, gives a well-organised speech, writes a creative short story (or poem or music), proposes a plan for experiment, integrates learning from different area into a plan for solving a problem, and formulates a new scheme for classifying objects (or events or ideas).

Behavioural Terms: Categorise, combine, compile, compose, create, devise, design, explain, generate, modify, organise, plan, rearrange, revise, rewrite, summarise, tell and write etc .

(v) Evaluation

Evaluation is concerned with the ability to judge the value of material (statement, novel, poem, research report) for a given purpose. The judgments are to be based on definite criteria. These may be internal criteria (organisation) or external criteria (relevance to the purpose) and the students may determine the criteria. Learning outcomes in this area are highest in the cognitive hierarchy, because they contain elements of all of the other categories, plus conscious value judgments, based on clearly defined criteria.

Examples: Judge the logical consistency of written Material, judges the adequacy with which conclusions are supported by data, judges the value of work (art, music, writing) by use of external standards of excellence.

Behavioural Terms: Appraise, compare, conclude, contrast, describe, discriminate, explain, justify, interpret, relate, summarise, support etc.

Affective Domain

Affective domain objectives deal with interest, attitudes, values, appreciation and adjustment. It future classified into five categories intended to be hierarchical in order.

Receiving (Attending)

Receiving is to orient the learner to learn. This is the first step that he is willing to learn what is being to him. The category of receiving has three different levels; the lowest level is the awareness or being conscious of something. The next point is that he is willing to receive and then he is attentive when something is given to him.

Examples: The students are aware of scientific activities in the school. They are willing to take part in scientific activities. They attend activities arranged by science club.

Responding

Responding level comes after the learner has given his attention. Responding includes behaviours like compliance and willingness to respond and getting satisfaction by responding.

Examples: Students respond to the questions asked by the teacher. Students raise hands to answer questions every time question is asked by the teacher. Students feel happy after answering the questions correctly. Students take pleasure in explaining scientific phenomena to others.

Valuing

The abstract concept is an important element of behaviour. At this level individual is not motivated by the desire to comply or obey but he is motivated because of his own valuing or assessment and commitment to the underlying value. The value system has slowly accepted and has come to be used by the student at his own criteria of worth.

Examples: Students have faith in the power of reasoning and methods of experimenting and discussions.

Organisation

When the learner develops certain values, he encounters situations for which more than one value is relevant. In such cases he is able to organise the values into a system.

Examples: students develop a plan for doing some scientific activities and school work at home.

Characterisation

Characterisation is identified by a value or value complex. The individual acts constantly in accordance with the values he has developed.
Examples: Students develop a code of behaviour based on scientific attitudes.

Psychomotor Domain

The psycho-motor domain concerns itself with levels o attainment on neuromuscular coordination. As the levels of coordination go up, the action becomes more refined, speedy and automatic. In this case five broad categories have been identified as given below.

Imitation

This is the lowest level of psycho-motor behaviour. It is represented by "convert inner rehearsal of the music system." There is very rudimentary in an act. (Impulsion and overt repletion)

Manipulation

This is the next higher level of psycho-motor behaviour. It involves following directions, selecting certain actions in preference to other and acting accordingly. (Following direction, selection and fixation)

Precision

This is the third category in which reproduction of operations is carried out with speed and refinement, giving the learner the ability to control (increase, decrease or modify), his action in response to requirements. (Reproduction and control)

Articulation

The learner is able to handle a number of actions in union, keeping in view their sequence and rhythms. (Sequence and Harmony)

Naturalisation

It is final stage in which the equivalent of perfect habituation ranging from automatisation to routinisation. At this level the performer does not expend any psychic energy in carry out an operation. His actions are more or less mechanic at without any conscious thinking or planning i.e. a more reflex action. (Automatism and Interiorisation)

Development of Skills under Psychomotor Domain

The pupil develops Observation Skills, Manipulation Skills, Drawing Skills and Reporting Skills.

Observation Skills

- Reads an instrument accurately.
- Takes observations in a systematic and sequential manner.
- Takes the number of observation necessary.
- Reads a graph accurately.

Manipulation Skills

- Selects appropriate apparatus, tools etc.
- Checks the tools, apparatus and equipments regarding its working
- Knows the limitation of the apparatus etc.
- Sets the apparatus in a proper way
- Performs the experiments with reasonable accuracy and neatness
- Makes correct substitution of formula (if any)
- Calculates the result accurately
- Interprets data and draws conclusion

Drawing Skills

- Draws neat, proportionate and correct diagrams
- Labels the diagram correctly
- Draws graph and selecting proper scale

Reporting Skills

- Presents the observations in an appropriate manner/sequence.
- Presents the calculations/results in proper sequence/manner/units.
- Calculates (and compares) the percentage error etc using appropriate symbols and formulas.
- Explains orally the procedures, precautions and limitation of the equipments, apparatus and experiments.

Differences between Educational and Instructional Objectives

Sl. No.	Education Objective	Instructional Objective
i	General aim or purpose that is stated as a broad and long-range outcome.	An intended outcome of instruction that has been stated in general enough terms to encompass a set of special learning outcome.
ii	Goals are used for policy making.	Goals are specific and observable.

1.2 Science Curriculum, Values of Science teaching, Interrelationship of various branches of Science, Scientific aptitude and attitude

1.2.1 Science Curriculum

The curriculum talks of a course to be run in formal schooling for achieving objectives set for some programme. The educational activities revolve about it. It declares educational efforts in pragmatic situation telling what to teach. It decides in totality of experiences that a child is expected to undergo. Most essentially curriculum should be in conformity with the aims and objectives of science education of a democratic society, which aims at making good citizen.

Since education is a dynamic process, the objectives in earlier days (acquisition and retention of information), and that of today have undergone a paradigm shift. The objective of this day may be like imparting a sum total of experiences through meaningful manifold activities in diverse situation that pupils may encounter in their numerous formal and informal contacts with teacher and other resources of the society in particular and whole of the globe in general, in addition to the courses of study.

The curriculum of the day needs to ensure that a pupil becomes not only master of a field but there also occur simultaneously evolution of balanced personality: that has concern for well being of whole humanity, has concern for environment, shows signs of scientific attitude, has concern for health, able to imbibe respect for cultural/ social heritage, inculcate values and changes it seeks as a result of development in global perspectives, impart knowledge & necessary operation skills to handle science/ technological gadgets, and not lastly (and addition is welcome), but awareness of the happening around them.

Criteria for an ideal Science Curriculum

Good science education is true to the child, true to life and true to science. This simple observation leads to the following basic criteria of validity of a science curriculum:-

(a) Cognitive validity: It requires that the content, process, language and pedagogical practices of the curriculum are age appropriate, and within the cognitive reach of the child.

(b) Content validity: It requires that the curriculum must convey significant and correct scientific content. Simplification of content, which is necessary to adapt the curriculum to the cognitive level of the learner, must not be so trivialised as to convey something basically flawed and/or meaningless.

(c) Process validity: It requires that the curriculum engage the learner in acquiring the methods and processes that lead to generation and validation of scientific knowledge, and nurture the natural curiosity and creativity of the child in science. Process validity is an important criterion since it helps the student in 'learning to learn' science.

(d) Historical validity: It requires that science curriculum be informed by a historical perspective, enabling the learner to appreciate how the concepts of science evolve with time. It also helps the learner

to view science as a social enterprise and to understand how social factors influence the development of science.

(e) Environmental validity: It requires that science be placed in the wider context of the learner's environment, local and global, enabling him/her to appreciate the issues at the interface of science, technology and society and preparing him / her with the requisite knowledge and skills to enter the world of work.

(f) Ethical validity: It requires that the curriculum promote the values of honesty, objectivity, co-operation, freedom from fear and prejudice, and develop in the learner a concern for life and preservation of environment

Science Curriculum at different stages

Consistent with the criteria above, the objectives, content, pedagogy and assessment for different stages of the curriculum are summarised below.

Primary stage: At the primary stage the child should be engaged in joyfully exploring the world around and harmonising with it. The objectives at this stage are to nurture the curiosity of the child about the world (natural environment, artifacts and people), to have the child engage in exploratory and hands on activities to acquire the basic cognitive and psychomotor skills through observation, classification, inference, etc.; to emphasise design and fabrication, estimation and measurement as a prelude to development of technological and quantitative skills of later stages; and to develop the basic language skills: speaking, reading and writing not only for science but also through science. Science and social science should be integrated as 'Environmental Studies' as at present, with health as an important component. Throughout the primary stage, there should be no formal periodic tests, no awarding of grades or marks, and no detention.

Upper primary stage: At the upper primary stage the child should be engaged in learning principles of science through familiar experiences, working with hands to design simple technological units and modules (e.g. designing and making a working model of a windmill to lift weights) and continuing to learn more on environment and health through activities and surveys. Scientific concepts are to be arrived at mainly from activities and experiments. Science content at this stage is not to be regarded as a diluted version of secondary school science. Group activity, discussions with peers and teachers, surveys, organisation of data and their display through exhibitions, etc. in schools and neighbourhood are to be an important component of pedagogy. There should be continuous as well as periodic assessment (unit tests, term end tests). The system of 'direct' grades should be adopted. There should be no detention. Every child who attends eight years of school should be eligible to enter Class IX.

Secondary stage: At the secondary stage the students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological modules than at the upper primary stage, and in activities and analysis on issues surrounding environment and health. Systematic experimentation as a tool to discover/verify theoretical principles, and working on locally significant projects involving science and technology are to be important parts of the curriculum at this stage.

Higher secondary stage: At the higher secondary stage science should be introduced as separate disciplines with emphasis on experiments and problem solving. The students may be given an option to choose the subjects of their interest freely, though it may not be feasible to offer all the different subjects in every school. The curriculum load should be rationalised to avoid the steep gradient between secondary and higher secondary syllabus. At this stage, core topics of a discipline, taking into account recent advances, should be carefully identified and treated with appropriate rigour and depth. The tendency to superficially cover a large number of topics of the discipline should be avoided.

Problems and outlook

Looking at the complex scenario of science education in India, three issues stand out unmistakably. First, science education is still far from achieving the goal of equity enshrined in our constitution. Second, science education, even at its best, develops competence but does not encourage inventiveness and creativity. Third, the overpowering examination system is basic to most, if not all, the fundamental problems of science education.

In this position paper, the Focus Group has attempted to address a range of issues related to science curriculum and problems in its implementation, but has particularly focused on the three issues mentioned above. First, we must use science curriculum as an instrument of social change to reduce the divide related to economic class, gender, caste, religion and region. We must use the textbook as one of the primary instruments for equity, since for a great majority of school going children, as also for their teachers, it is the only accessible and affordable resource for education. We must encourage alternative textbook writing in the country within the broad guidelines of the national curriculum framework. Information and Communication Technology (ICT) is also an important tool for bridging the social divides. ICT should be used in such a way that it becomes an opportunity equaliser, by providing information, communication and computing resources in remote areas.

Second, we believe that for any qualitative change from the present situation, science education in India must undergo a paradigm shift. Rote learning should be discouraged. Inquiry skills should be supported and strengthened by language, design and quantitative skills. Schools should give much greater emphasis on co-curricular and extra-curricular elements aimed at stimulating investigative ability, inventiveness and creativity, even if these elements are not part of the external examination system. We strongly recommend a massive expansion of non-formal channels (for example, a truly large **scale Science and Technology Fair** with feeder fairs at cluster/district/state levels) to encourage schools and teachers to implement this paradigm shift.

Third, we recommend nothing short of declaring examination reform as a National Mission (like other critical missions of the country), supported by funding and high quality human resources that such a mission demands. The mission should bring scientists, technologists, educationists and teachers on a common platform and launch new ways of testing students which would reduce the high level of examination related stress, curb the maddening multiplicity of entrance examinations, and research on ways of testing multiple abilities other than formal scholastic competence.

These reforms, however, fundamentally need the over-arching reform of teacher empowerment. No reform, however well motivated and well-planned, can succeed unless a majority of teachers feel

empowered to put it in practice. With active teacher participation, the reforms suggested above could have a cascading effect on all stages of science teaching in our schools.

1.2.2 Values of Science Teaching

It is quite clear that science subject is very much valuable and psychologically based and very closely connected with our day-to-day life, is justified to be included in school curriculum. Therefore, the claims of science for a place in school curriculum are now well recognised. Hence, it must form a part and parcel of school curriculum. Values of science in school curriculum are discussed in detail as:

(i) Intellectual Value

- Introduced new ways of thinking and reasoning so consciousness of man is developed. Development from amoeba to man seems to have been the increase in consciousness.
- Scientific thinking is an organised manner. It is organised common sense applicable to all life situations.
- Einstein's view of enriched consciousness is by making man acquainted with a new and valuable way of thinking.
- Science gratifies intellectual universe by giving a real insight of ourselves. Science develops intellectual abilities like sense of meaningful observation, fact reasoning, purposeful thinking, concentration, critical in observation, avoids prejudices and biases, helps individuals to sharpen their intellect, gratifies and quenches the thirst for knowledge.
- Knowledge for knowledge sake is an aim which is unquestionable.

(ii) Utilitarian Values

So far as utility and importance in daily life is concerned, science is second to none. A network of science gadgets everywhere in our daily life is the innovation of science. They are the Television, Video, Computer, Robots and Mobile phones etc. Right from the cradle to the grave, all our activities are controlled and fashioned by science. The vast storehouse of natural power such as the wind, the waterfall, heat of the sun, are harnessed by science for the relief of human drudgery and for raising the standard of life.

Science has unveiled the certain of nature to keep into the mysteries. It has restored eyes to the blind, hearing to the deaf, legs to the lame, found out ways of health, atomic energy, radioactive isotopes for improvement of crop, increase in food production. In the field of agriculture science has improved the quality and quantity by means of reproduction, hybridization. To raise the standard of any nation two things are necessary, scientific knowledge and a population sufficiently educated to understand to apply it to daily life.

Telephone and wireless have enable man to reach in moon and other planets. Man is able to explore mountains, deserts, oceans etc. It has been playing a utilitarian value to improve the standards of life of the people and has been a helping instrument in guiding daily living and life styles.

(iii) Moral Value

Of the great values that condition our lives worth living are –Truth, Beauty and Goodness. A man of science is concerned with the disinterested passion of truth. Science is an activity where truthfulness is the most essential condition to success. A scientific attempt which is misrepresented or deliberately made fictions and false conclusions merely declines the whole world.

Science strengthens the commitment of free enquiry and the quest for truth. It loosens the bands of dogmatisms and acts as a powerful dispeller of fear, superstition and fatalism. Science builds a love for truth. As the success of science depends on truth, scientists cannot ignore it and never manipulate observations and never misinterpret the facts. The qualities of honesty, integrity, punctuality, determination, patience, self-control are all the moral values the scientists have.

(iv) Aesthetic Value

Because of its practical application science meets one of the deepest needs of human nature which manifests itself as the desire for beauty. If science is to be pursued with full vigour and zest and is to become a mighty force it is it drive its nourishment from cultural and spiritual heritage. The search for universal laws and comprehensive theories are the manifestation of the aesthetic motive. Truths are beauty and discoveries of nature are the concerns of science and everything in nature is beautiful. Every scientist relishes the aesthetic aspect of his invention and discoveries. Scientist feels an intrinsic charm in revealing the harmony of nature. Nature is governed by general laws. Science is as an art as it unfolds beauty.

(v) Culture Value

Science has unfolded the culture and civilization of a country from time to time. It has a direct influence is dispelling many traditional beliefs, consequences of new techniques of science, social organisations have been amply charged. New control of science over the environments is bringing up a new philosophy involving a changed conception of man's place in the universe.

Science has its own literature. The history of scientific development and the spirit of sacrifice exalt science to a position higher than the humanistic studies. Through the practical application of scientific discovery our civilization is undergoing constant change. The welfare of our civilization is now almost wholly dependent upon scientific progress society is to respond with adequate intelligent control.

(vi) Disciplinary Value

Science develops and controls the mental abilities of an individual. It also helps in developing the habit of truthfulness, sense of logic reasoning, creative and critical thinking. It promotes concentration, systematic work, healthy exchange of thoughts and hard work habits. It trains mind and develops the habit of disciplined life along with working confidence.

(vii) Vocational Value

Science has generated a number of vocations and helps individuals in earning their bread. It has become an integral part of Dairy, Poultry, Pisciculture, Agriculture, Horticulture, Banking, Teaching and Factories. Science plays a vital role in learning and acquiring different professions and their professional skills. It has solved the problems of leisure. The study of science at school develops many hobbies and productive activities in the later life of the students. Scientific hobbies motivate to adopt simple cottage industries like manufacturing soaps, detergents, face creams, scented oils, powders, polished, paints, repairing of TVs, computers etc.

(viii) Social and Psychological Value

Science and society have become the two sides of one coin. Science gives impetus to progress of society by new ideas, thoughts, and discoveries and brings the whole world very close. Psychological principles of all indicating the social and psychological values.

(ix) Training in Scientific Method

The study of science trains the students in solving the problems through scientific method. Scientific method has following steps:

- Making an accurate survey
- Setting up a method
- Collecting data
- Drawing conclusion

All these are the cardinal principles of scientific method which help in solving problems in new situations.

(x) Development of Scientific Temper/Attitude

Scientific attitude includes critical observation, open mindedness, suspended judgement, free from superstitions and false beliefs which are to be developed in students. Scientific attitude once developed in the student proves useful in later life of the child.

1.2.3 Inter relationship of varies branches of science

Correlation in Science Teaching

Correlation is the reciprocal relationship between various subjects of the curriculum. Curriculum is divided into various subjects, only for the sake of convenience; but there is vital connection between them. When the study of one subject requires the knowledge of other subject, they are said to have correlation. Carter V. Good defines correlation as " bringing together the elements of two or more subject matter fields that bear on the same large problem in such a way that each element is reinforced, broadened and made richer through its association with the elements from the other subject fields".

The child is interested to learn the things which are related to his experiences. They cannot learn the various subjects in isolation. The correlation of different subjects is very essential for checking artificiality of treatment and for achieving unity of knowledge. It makes study easier, more interesting and natural.

Advantage of correlation

- The student realizes the basic unity of knowledge and similarity in the methods of investigation through correlation.
- It encourages all round development and growth of a child.
- It helps widen the mental horizon of students.
- It assists in brining closer the school and society.
- It establishes close relationship between experience and knowledge.
- Correlation can lead to more effective learning as the same topic is dealt with in several different situations and viewed from different angles.
- It prevents narrow specialization.
- It makes education natural.
- It makes the lesson interesting by brining in the other subjects and experience.
- The students become capable of transferring learning from one situation to the other through correlation.
- It makes the subjects more meaningful.
- Learning by doing is fostered while organising projects to correlate different subjects.
- It broadens the teacher's outlook.
- A teacher by correlating various subjects can clearly justify, unity off all knowledge and its usefulness in daily life.
- It helps teachers to learn more books and keep their knowledge up-to-date.

Limitation of Correlation

- It is not applicable for higher classes when the subject becomes more specific.
- All subjects such as cultural subjects cannot be taught through correlation.
- It is not use in all teaching situations.
- It cannot be applied with equal efficiency on all occasions by all teachers.

- It needs high expertise on the part of teacher.

Correlation of Science with Other Science Subjects

All the branches of science are interdependent on each other; for example, Physics and Chemistry are intimately related to each other through the following: electroplating, study of atmosphere, spectrum analysis, and crystallography and so on. Again, physics and chemistry are related to biology through biophysics and biochemistry. All impulses in a living organism are electrical impulses and are conducted through weak solutions in the organism. Heredity operates through nucleic acids. Genes are chains of amino-acids that regulate the growth of different organs. Animal behaviour is controlled by chemicals (hormones).

(i) Physics in relation to Chemistry

The study of structure of atom , radioactivity, X-ray diffraction etc. in Physics have enabled Chemists to rearrange elements in periodic table on the basis of atomic number; have better understanding of chemical bonding and compels chemical structures.

(ii) Physics in relation to Biological Sciences

The optical microscope developed in in Physics is extensively used in the study of biological samples. Using an electron microscope, the structure of biological cells is studied. X-ray discovered in Physics have a variety of applications in biological sciences. The radio-isotopes are used for the treatment of cancer and so on..

(ii) Physics in relation to Mathematics

Theories in Physics often made use of mathematical concepts. Mathematics has infact served as a powerful tool in the development of modern theoretical Physics. For instance, the knowledge of Algebra, Trigonometry, Differential and integral Calculus, etc. is very helpful in various branches of Physics.

(iv) Physics in relation to Astronomy

The giant astronomical telescoped developed in Physics are used for observing planets and other heavily bodies in the sky. Radio telescopes have enabled the astronomers to observe distant limits of the universe.

(v) Physics in relation to other Sciences

The other sciences like Biophysics,, Geology, Metrology, Oceanography, Seismology etc. also use some of the laws of Physics.

(vi) Science and the Social and Physical Environments

It has been said that science has gone deep into our everyday affairs. We are living in an age of science and all our activities are controlled and governed by science. Just sit in a modern room and you will feel how science adores us and gives comfort. Everything around us directly or indirectly concerns science. It has changes the whole pattern of society and has affected the social as well as the physical environments. The understanding of these changed and complex environments, for a successful living, is possible only through the knowledge of science. It is, therefore, obligatory on the part of the science teacher that he should relate the classroom teaching with the social and physical environments by quoting example from the daily life of the child. He should take the students to a factory or on excursion while dealing with the topic concerning these. The teaching of science will be forfeiting its purpose if it does not take into account the experiences of.

(vii) Science and Hygiene

Hygiene cannot be taught properly unless we know about the human structure; this can be made known with the help of anatomy and physiology. These two science subjects help in proper understanding of hygiene. Principles of dietics are determined on the basis of scientific principles. Food is very important for hygiene. Ingredients of food can be determined on the basis of chemical examination and biological experiments. Similarly zoology and diet also find themselves related with each other. In short, we may say that as teacher of hygiene cannot do justice to his subject unless he has studies science well. Therefore, it shall not be out of place to say that these two subjects are closely related.

Thus, it can be concluded from above discussion that science is very much essential in successful learning of other subjects. On the other hand the knowledge and skills required through the study of other subjects also influence and affects the study of science.

1.2.4 Scientific Aptitude and Attitude

Scientific Aptitude

Importance of science learning is being recognized more and more in the context of contemporary society which is highly scientific as well as technical. Effective science learning in this context is not only necessary for one's individual development; it also helps learner to contribute significantly for the development of nation. **In the Dictionary of education (Good, 1959),** aptitude is defined as "a pronounced innate capacity for or ability in a given line of endeavor such as particular art, school subject or vocation". In this definition, an aptitude refers to an individual's inborn potentialities or capacities which are indicative of some special abilities. 'Aptitude' in Great Illustrated Dictionary [in Rao, 1996) is considered as "a natural talent, skill or ability, quickness in learning and understanding". In the above two definitions, it has been emphasized on that an aptitude refers to the capacity of an individual to be skilled in some work receiving formal and informal training.

Aptitude is not a specific skill; rather it is the capacity to acquire that specific skill **(Freeman, 1965**). If an individual has no aptitude for a particular type of work, he/she will not be skilled or proficient in that task in spite of training given to him/her. Whereas, right aptitude of a person, in any specific field, indicates his/her ability of acquiring skills in that particular field, on the basis of which a prediction may be made regarding the amount of improvement of that person in that field, which further training might effect. As a matter of fact, aptitude is influenced by both biological and cultural factors of an individual.

"Scientific aptitude is a complex of interacting hereditary and environmental determinants producing predisposition or ability in science. Through these abilities, it is possible to predict future accomplishment of a person in science" defined by **Rao, 1996**. Researcher has also explained that scientific aptitude depends upon a variety of factors. Presence of certain study skills and persistence in learning science, motivation, satisfaction derived from learning science subjects, socio-economic factors and cultural background are some of the important determinants of scientific aptitude.

Scientific aptitude helps a learner in developing vocabulary, in recognizing a number sequence correctly, perceiving spatial relationship, relating variables by proper formulation, in understanding completely a given set of information, and functions of different devices etc. in Science and also in applying those in explaining and predicting various happenings following essential steps of a scientific method successfully in learning Science (which is acquired through proper Science education). This ultimately leads to prediction in learner's future accomplishment in the area of learning Science.

A man who has scientific mind lives more happily and adjusts to it. Hence it is the responsibility of the teacher to develop scientific aptitude among children that the coming generation leads a happy life in the world of science. Aptitude is not totally inherited quality we can modify it if not completely but to a considerable extent. One who has scientific aptitude, not only perceive the knowledge correctly but also apply it in understanding new situations. The application of knowledge in problem solving is another ability of an individual having scientific aptitude. The scientific aptitude may be considered as in inferred state of readiness to react in a characteristics way towards particular type of situations. One who is scientific minded and has aptitude for science is curious to solve problems curious to know things and raise significant questions with reference to observed phenomenon.

Operational dimensions of Scientific Aptitude

Muchinsky (2004) has identified the following primary mental abilities in relation to aptitude in any specific field. These are –

(a) General intelligence – general learning ability

(b) Verbal ability – vocabulary

(c) Numerical ability – mathematical reasoning in problem solving

(d) Spatial ability – ability to visualize and rotate objects in space involving figures.

(**e) Memory** – ability to recall or recognize after a brief exposure to words, symbols, numbers, and figures.

(f) Perceptual speed – ability to work quickly and accurately in scanning and perceiving similarities and differences in words, numbers, and pictures (mostly related with clerical aptitude).

(g) Psychomotor ability – ability to move hands and figures and co-ordinate their movement. In relation to aptitude, particularly in science or science related domain,

Scientific Attitude

In modern time, the chief aim of education is to enable a citizen to develop scientific attitude to think objectively and base his conclusion on tested data. By developing scientific attitude in a person, certain mind sets created in a particular direction. Such mind sets are may be developed either by direct teaching in school or by out of school experiences gained by the people. Attitude ate developed and learned, they are not in born. Attitude can be changed through experiences especially in children. These are the result of experiences. Through out of the school experiences contribute to large extent yet direct teaching does modify the attitude of young pupil. Attitude are mental state or individual outlook towards, people, object, events etc. The scientific attitude may be operationally taken as the generalised attitude towards the universe of science, content of which is being measured in term of its favourableness or unfavourableness. Allport (1935) opines that, "the scientific attitude refers to the feelings, opinion, beliefs in and about appreciation that an individual forms as a result of interacting directly or indirectly with various aspect of the scientific enterprises and which exerts a direct influence on their behavior towards science."

Scientific Attitude: Meaning and concept

Scientific attitude refers to an individual's outlook towards life. It means willingness to adopt scientific approaches and procedure for resolving issue, assessing idea or information. Attitude is defined as a condition, a stabilised mental set which expresses itself in a tendency to react to any, member of class of stimuli in the same general way. Scientific attitude predisposes a person to engage in responsible action after weighing the possible consequences of alternative, option, using rational arguments based on evidence. She distinguish between scientific evidence and personal option and between reliable and unreliable information remains open to new evidence and the tentativeness of scientific knowledge and recognises that science and technology are human endeavours. Some other manifestations of the scientific attitude are questioning, suspension of judgment, appraisal of different sides of an issuer, verification of knowledge, curiosity and appreciation of the natural and human made world, open mindedness, intellectual honesty, cooperation and tolerance of the point of view of other people. The scientific attitude presents a systematic account of the cognitive and social feature of science. Attitude embraces three distinct components: the affective, the behavioural and cognitive. According to Koballa

(1990), attitude is learned either actively or vicariously and therefore, can be taught. Hence essentially, scientific attitude involve feelings, opinion, beliefs appreciation, which individual have formed as a result of interacting directly and indirectly with various aspect of the scientific enterprise **(Hasan Bilch, 1975, Munby 1983)**. It also covers emotional reactions, someone exhibit toward science. The term "scientific attitude," on the other hand is previous as desirable attribute of scientists in professional work and could be categorized as interest, adjustment, appreciation as well as values. These attributes included suspended judgement, curiosity open rationality, objectively and questioning attitudes **(Kozlow and Nay, 1974).**

Spread of scientific attitude in the society is much more than the spread of science and technology. Scientific attitude is neither a collection of knowledge or facts, although it promotes rational thinking. It is something more. It is an attitude for mind which calls for a particular outlook and pattern of behavior. It is of universal applicability and has to permeate through our society as the dominant value system, powerfully influencing the way we think and approach our problems-political, social, economic, cultural and educational. The spirit of inquiry and the acceptance of the right to questioned are fundamental to scientific attitude. Its call upon one to ask 'how' the 'what' and the 'why' of an object, event or phenomenon. Its further calls upon one to exercise the right to question, provided of course, the questioning of an existing theory, hypotheses, or statement or social situation is done in accordance with the scientific method and is not a merely a base assertion of one's belief. Scientific attitude is, therefore, incompatible with the acceptance of authorities of all kinds or of 'high priests' who may not be questioned. It lead to the realisation that event occur as a result of interplay of understandable and desirable natural and social forces and not because someone, however great, so ordained them. These forces are often complex and intertwined and have to be analytically disentangled.

Scientific attitude is compatible with observation and insight, reasoning and intuition, systematic work, creative impulse. It gives rise to an attitude of mind which while being conscious of vast area of ignorance, is nevertheless, optimistic about human ability to gradually unravel the mysteries that surround us. In this process, scientific attitude become a part of culture, a philosophy, and a way of life which live to pursuit of truth without prejudgement. Scientific attitude implies the recognition that knowledge often progresses by disproving earlier ideas, beliefs, theories and laws. It considers knowledge as open ended and ever evolving. Its lay emphasis on verifiability repeatability, whenever possible and on the fact their scientific theories, laws and fact allow one to make prediction which can be tested. It recognizes that answer to too many questions that may be asked at any given time may not be available at that time. It then demand courage and humility to say, "I do not know." Inherent in scientific attitude is asystem of value judgment. The inclusion of scientific attitude in our society would result in our people becoming rational and objective, thereby generating a climate favouring an egalitarian, democratic, secular and universalistic outlook. Consequently scientific attitude cannot flourish in a grossly in egalitarian society where 50 per cent of population lives below the poverty line and almost 70 per cent of our people, especially females, are illiterate. Social justice, widespread

education and unrestricted communications are, therefore pre-requisites for spread of scientific attitude and for optimizing the results of science and technology.

The term attitude begins as a relatively simple one dimensional concept consisting of the affective component of psychological object and has grown into a complex multi-dimensional concept of experience cognitive, affective and co-native. Attitude are ethics, how one is disposed toward a particular thing, place or a person reflects one's attitudes. An attitude is hence a condition of mind that brings in imagination and emotional state which are the outcome of previous experiences. Attitude condition behavior and therefore are of paramount importance in education. Thurston and Chave defined attitude as sum total of a man's behaviors and feelings, prejudice and biased, preconceived notion, ideals, threats, and convictions about any specific activities, it defer from option which mean a verbal statement hypothesized to be symptomatic of attitude.

In other words attitude is what you feel and opinion is what you express. These may be general or specific. In the first moving word and conflicting demand of the society, individual is faced with more problems that had made difficult to adjust. Therefore, there is need for developing right sort of attitude to avoid any mental conflicts. One of the important attitude that must be inculcated in students to make them useful and socially efficient citizen is the science subjects in particular. Because developing scientific attitude is potential means of eliminating intolerance, superstitions, obscurantism which are considered socially undesirable.

Scientific attitude refer to an individual's outlook toward life. It means a willingness to adopt scientific approaches and a procedure for resolving issues/assessing ideas or information.

Component of scientific Attitude

- Identifying relationship between cause and effect
- Believing in intellectual integrity
- Rising above blind belief and dogmas
- Having full faith and dislike
- Developing the capacity of clear thinking and realising the new idea
- Accepting the authentic idea even with caution
- Presenting a critical and constructive attitude while solving a challenging problem
- Arriving at no conclusion at all on the availability of incomplete a false data.
- Basing conclusion on tested to data only
- Keeping certain exception into consideration while determining a principle

Components of scientific Attitude are also classified as follows:

- Eliminating of belief in superstitions
- Curiosity to know
- Open mindedness

- Facts with proofs
- Critical evaluation
- Accuracy in observation
- Change of opinion after getting evidence
- Attitude to discover
- Respect for other views.
- Biased/prejudiced notions

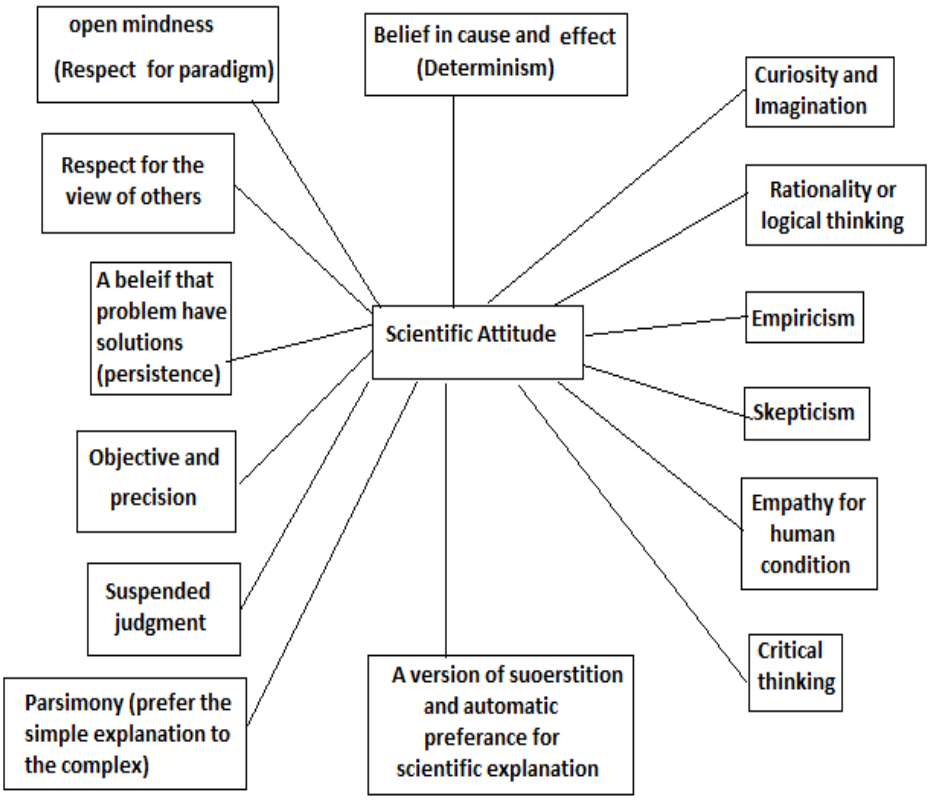

Figure 1.3 Components of Scientific Attitude

Characteristics of students having Scientific Attitude

- A student with scientific attitude
- Does not believe in superstitions
- Is curious to know his varied environment
- Is open minded
- Believes that nothing can happen without cause
- Does not accept statement as facts without sufficient proof
- Is critical minded
- Is careful and accurate observer
- Is willing to change his opinion on getting evidence
- Respect others point of views
- Is not prejudiced or biased in his outlook

- Accepts no conclusions on inadequate evidence
- Likes to discover things
- Does not base his conclusions on inadequate evidence

Indicators of Scientific Attitude

Attitude is more generalized aspects of behavior than are process skill. However, we can still identify indicators of process skills, except that they have to be for any individual activity.

The following are some indicators of Scientific Attitude:

- Willingness to collect and use evidence.
- Reporting actually what happened, even if it was conflict with expectation.
- Querying and checking part of evidence which do not fit into the pattern of other findings.
- Querying an interpretation or conclusion for which there is insufficient evidence.
- Willingness to changes ideas in the light of evidence of (Flexibility combined with open mindedness).
- Being prepared to change an existing idea when there is convicting evidence against it.
- Spontaneously seeking alternative ideas rather than accepting the first one which fits the evidence.
- Realising that it is necessary to change idea when different ones make better senses of evidence.
- Considering the points in favour and against way in which investigation was carried out.
- Spontaneously reflecting on how the procedures might have been improved.

Development of Scientific Attitude

The sole responsibility of developing scientific attitude among the student lies on the teacher who can manipulate all the situations to instill in the pupils the characteristic features of scientific attitude and at the same time present himself as an example to the students for his intellectual honesty, respect for other point of views, unbiased and impartial behaviors in his dealing and like. This will create a favourable and permanent impression on the students to adopt the same attitude which their teacher has however, they can develop scientific attitude among the students in the context of –

- Curriculum
- Physical facilities
- Opportunity for practical work

A large majority of the school are of the view that enthusiastic teacher can help in developing the scientific attitude through the curriculum. The teacher should suggest the project which give the pupils training in problem-solving. Reading more books in science develop scientific attitude more than those who read only one text-book.

Democratic atmosphere in the classroom also helps in developing certain desirable attitude in the students. Such atmosphere will infuse a spirit of healthy criticism. There will be no wishful or biased thinking on the part of the students, they are free to question and difficulties removed.

For removing the superstitious and false belief from the mind of the student, the teacher should usually put such type of question as "what evidence or proof have you for this belief." This will also develop in them in open mindedness and critical thinking. They should be taught not to take the think for granted because they appear in print or are spoken by a big man. But too much of stress on this point may be proving harmful.

Once the characteristic of a person having scientific attitude identified and scientific attitude operationally defined, it was finally suggested that in order to develop scientific attitude does. The development if scientific attitude among the learning must be a primary objective of teaching science at any stage of the school curriculum.

Opportunities of practicing work should be provided in schools

This helps informing and practicing work should be provided in school. This help in forming and practicing good attitudes. The students should perform the experiments themselves and find out truth of what they learnt in their theory. They should be taught to suspend judgment until sufficient evidence is secured.

They should be instructed to observe critically and accurately and to report only what they see. Their habit of copying thing should be discouraged. It is quite obvious that most of the students get the chance of practicing the attitudes they have already acquired.

But it is not easy to assess the scientific attitude. We are not aware of any satisfactory test calculated go measure scientific attitude of pupils. However, there is enough evidence to show the active desire of teacher to cultivate habits of thought and action that gradually leads to the acquisitions of scientific attitude.

Satisfaction of Curiosity

Children are endowed with a natural gift of curiosity. They are very curious to know how and why of all phenomenon and events. The opportunity should be given to satisfy and nourish this distinct by encouraging the children to ask question and have patience in answering their question in a satisfactory way they should be given opportunity for the use observation and experimentation of the things and events for carrying them ahead in this satisfaction and nourishment of their curiosity.

To get rid of the Superstitions

Children in tender age are very easily influenced and impressed by the baseless beliefs and superstitions spread among their elders. Therefore, the study of science and efforts of the teacher

should be essentially directed in removing the impression of the false beliefs and superstitions. He must ask now his student to test the validity of these beliefs by collecting relevant evidence and proof mainly based on their self-observation, experiences and experimentation.

Proper Way of Teaching

If the teacher wants to develop in their students the quality of scientific attitude, they must make their method of teaching more scientific. The teachers should encourage the student to carry on independent tests and experiments in the laboratories and investigation.

Utilising Co-curriculum Activities

Besides giving importance to academic science education, it is more important and essential to provide all facilities for their relevant activities to promote free thought and action to students.

Education trips, tour, nature study, entertaining visit, science fair, science exhibition, science museum and other meaningful work should be done.

Proper Environment of the Classroom

The science classroom, laboratories and other place of science activities should be well-loaded with a science and spirit of scientific attitude.

- Inspiring for the study of scientific literature.
- Self-example by the teacher.

Implication of Scientific Attitude

The views regarding scientific attitude expressed at a workshop conducted by the NCERT in 1971 can be summarised as follows. A pupil who has to develop scientific attitude:

- Is clear and precise in his activities and values clears and makes clear and precise statement.
- Always basis his judgment on verified facts and not on opinion.
- Prefers to suspend his judgment if sufficient data is not available.
- Is objective in his approach and behaviour.
- Is honest and truthful in recording and collecting scientific data.
- After finishing his work take care to arrange the apparatus, equipment etc. their proper places.

Thus, scientific attitude has laid foundation for the development of modern technology. This attitude has brought a drastic change in the human behavior and thinking and creativity of the mankind. People are utilizing those technologies in various areas and discipline. For the instant invention of the computer from micro to super computer has change the figure of world in every aspect. Technology is growing rapidly there by making the life of the human being very comfortable and luxurious. This obviously encourages the person to create various technology

which may meet with their every requirement. Today's world is due to creativity and scientific attitude of the mankind.

1.3 Innovations in Science teaching

Innovation means the introduction of something new and useful, for example, introducing new strategies or modified methods, techniques, practices, products and services. The definitions of innovation include:

- Process of making improvements by introducing something new
- Process of implementing new ideas for improvement of teaching learning process
- An idea, strategy, method or device
- Changes that create a new dimension of performance in any aspect of teaching-learning
- A creative idea that is realized through the use of alternative strategies or techniques.
- Capabilities of realising a desired change continuously in order to sustain it over a period of time.

Innovations in Science teaching include the following seven important dimensions:-

(i) Ancient Scientific knowledge in Recent Perspectives

(a) Science and Technology knowledge in Ancient Literature, Monuments and Scriptures
(b) Evolution of Scientific knowledge
(c) Indigenous Scientific knowledge and its linkage with Modern Science
(d) Traditional wisdom and Scientific knowledge

(ii) Knowledge – Skill integration in School Sciences

(a) Knowledge & Skill integration in curriculum practices
(b) Approaches and strategies of knowledge – skill integration
(c) Life skills development in School Sciences
(d) Complementarities in Science and Technology
(e) Trans-Disciplinary approaches in School Sciences

(iii) Digital Media and Science Education

(a) E-learning [Multimedia, ICT, internet, Open Educational Resources (OER), Massive Online Open Courses (MOOCs) etc.] in Science Education
(b) Digital life style and Science Learning
(c) Web 2.0 & 3.0 Technologies in Science Education
(d) Digital Platforms – edX, Coursera, Swayam, e-Pathshala, Swayamprabha etc.
(e) Futuristic Scenario of Digital Media in Science Education [example: **Classroom Of The Future (COTF)** by NASA of USA]

(iv) Nurturing Scientific Creativity

(a) Scientific Creativity: Content and Process
(b) Scientific Talent through School Sciences
(c) Science Process Skills and Scientific Temper
(d) Nurturing Scientific Creativity beyond classroom

(v) Emerging Trends in Curriculum and Assessment in Science Education

(a) Current approaches and of curriculum development and transaction
(b) Enhancing learning outcomes in Science
(c) Process and product evaluation in Science
(d) Promoting equity and inclusiveness in Science Education
(e) Online Assessment in school Sciences

(vi) School Science for sustainable development

(a) Science, Technology and Society (STS)
(b) Environmental sensitivity and concerns
(c) Greening school curriculum and curriculum practices
(d) Health, hygiene and well-being
(e) Science for peace, ethics and values

(vii) Professional development of Science Teachers and Teacher Educators

(a) Best practices in Science Teacher preparation
(b) Best practices in in-service Science Teacher Training
(c) Challenges & opportunities – Global and Local
(d) Initiatives/programmes for Science Teachers

Short Questions with Answers

Marks - 2

Q. Define educational objectives.

Ans: According to E.S. Bloom, "Educational objectives are not only the goals towards which curriculum is shaped and towards which instruction is guided, but they are also the goals that provide the detailed specification for the construction and use of education techniques."

According to E.J. Frust, "An education objective may be defined as a desired change in behaviour in a person that we are trying to bring about through education."

Q. Give two differences between aims and objectives.

Ans: Differences between aims and objectives are given in the following table:

Sl No	Aims	Objectives
i.	Aim is a general declaration of intention which gives directions to a teaching programme.	Objective is a particular point in that direction.
ii.	Aim is the answer to the question of why a subject is taught.	It is an answer to the question of what will be achieved after the teaching of a topic.

Q. Differentiate educational from instructional Objectives.

Ans: Educational objectives vs. instructional Objectives:

Sl. No.	Education Objective	Instructional Objective
i.	General aim or purpose that is stated as a broad and long-range outcome.	An intended outcome of instruction that has been stated in general enough terms to encompass a set of special learning outcome.
ii.	Goals are used for policy making.	Goals are specific and observable.

Q. State the nature of Science curriculum at the Secondary stage.

Ans: At the secondary stage the students should be engaged in learning science as a composite discipline, in working with hands and tools to design more advanced technological modules than at the upper primary stage, and in activities and analysis on issues surrounding environment and health. Systematic experimentation as a tool to discover/verify theoretical principles, and working on locally significant projects involving science and technology are to be important parts of the curriculum at this stage.

Q. What is meant by utilitarian value of Science teaching?

Ans: A network of Science gadgets everywhere in our daily life is the innovation of science. They are the Television, Video, Computer, Robots and Mobile phones etc. Right from the cradle to the grave, all our activities are controlled and fashioned by Science. The vast storehouse of natural power such as the wind, the waterfall, heat of the sun, are harnessed by Science for the relief of human drudgery and for raising the standard of life.

Q. What is meant by Scientific attitude?

Ans: Scientific attitude refer to an individual's outlook toward life. It means a willingness to adopt scientific approaches and a procedure for resolving issues/assessing ideas or information. Scientific attitude includes critical observation, open mindedness, suspended judgement, free from superstitions and false beliefs which are to be developed in students. Scientific attitude once developed in the student proves useful in later life of the child.

Q. How Physics is related to Chemistry and Biological Sciences?

Ans: (i) Physics in relation to Chemistry

The study of structure of atom , radioactivity, X-ray diffraction etc. in Physics have enabled Chemists to rearrange elements in periodic table on the basis of atomic number; have better understanding of chemical bonding and compels chemical structures.

(ii) Physics in relation to Biological Sciences

The optical microscope developed in in Physics is extensively used in the study of biological samples. Using an electron microscope, the structure of biological cells is studied. X-ray discovered in Physics have a variety of applications in biological sciences. The radio-isotopes are used for the treatment of cancer and so on..

Q. Distinguish between attitude and aptitude.

Ans: *An aptitude is a component of a competency to do a certain kind of work at a certain level, which can also be considered "talent". Aptitudes may be physical or mental. Aptitude is not knowledge, understanding, learned or acquired abilities (skills) or attitude. The innate nature of aptitude is in contrast to achievement, which represents knowledge or ability that is gained.*

- *Attitude is positive / negative / indifferent feeling towards a person, object, event or idea; whereas aptitude is a competency to do certain kind of work.*
- *Attitude is associated with character or virtues; whereas aptitude is associated with competence.*
- *Attitude underpins the character, virtues and moral values; whereas aptitude determines if the person would develop desired skills to do a task.*

Q. What is meant by innovation in science teaching?

Ans: Innovation means the introduction of something new and useful, for example, introducing new strategies or modified methods, techniques, practices, products and services. The definitions of innovation include:

- Process of making improvements by introducing something new
- Process of implementing new ideas for improvement of teaching learning process
- An idea, strategy, method or device

- Changes that create a new dimension of performance in any aspect of teaching-learning

Probable Questions

Very short answer type questions **Marks - 2**

1. Define educational objectives.
2. Give two differences between aims and objectives.
3. What is meant by cognitive domain?
4. What is meant by affective domain?
5. What is meant by psychomotor domain?
6. State the nature of Science curriculum at the upper primary stage.
7. State the nature of Science curriculum at the Secondary stage.
8. State the nature of Science curriculum at the Higher Secondary stage.
9. What is meant by utilitarian value of Science teaching?
10. What is meant by Scientific attitude?
11. What is meant by Scientific temperament?
12. Distinguish between Scientific attitude and Scientific temperament.
13. How Physics is related to Chemistry and Biological Sciences?
14. How Physics is related to Mathematics and Astronomy?
15. *Distinguish between* Scientific *attitude and* Scientific *aptitude.*

Short answer type questions **Marks - 5**

1. Explain Bloom's taxonomy of educational objectives.
2. What is meant by instructional objectives? How it is important for teachers to formulate instructional objectives?
3. Explain various stages of Science curriculum in schools.
4. Highlight different dimensions of innovations in Science teaching.
5. How will you formulate specific objectives in behaviourial terms in teaching of Physical Science?
6. In the light of characteristics of good behavioural objectives, write five behaviourial objectives on any topic of Physical Science.

Long answer type questions **Marks - 10**

1. Explain aims and objectives of teaching Physical Science teaching at the Secondary level.
2. What should in your opinion be the objectives of good Physical Science teaching? How would you achieve your views?
3. Do you consider the present Physical Science teaching in our schools is quite satisfactory? If not, what should be the objectives to bring about its improvement?
4. What are the three domains of educational objectives? Give example of each of them

Unit – 2 Strategies of Science Teaching: Features, Limitations and Comparison of different methods

2.1 Lecture Method
2.2 Demonstration Method
2.3 Heuristic Method
2.4 Laboratory Method
2.5 Project Method
2.6 Computer Assisted Instruction (CAI)
2.7 Problem Solving Method

A teaching method comprises the principles and method used for instruction. Commonly used teaching methods may include class participation, demonstration, recitation, memorization or combination of these. The choice of teaching method to be used depends largely on the information or skill that is being taught, and it may also be influenced by the aptitude and enthusiasm of the students. In order to make children learn effectively, the teacher has to adopt the right method o teaching. In the field of science, teachings methods play an important role along with its content. These teaching methods are determined by the teacher keeping in mind the capability of students and the curriculum. Thus, with the help of these methods the teacher imparts understanding of the subject matter along with the knowledge of the curriculum.

Definitions of Method

According to dictionary "A method is a way of doing things. Method deals with how to teach. Thus method is an overall plan of teaching approach".

According to Anthony "Method is an overall plan for the orderly presentation of language material, no part of which contradicts and all of which is based upon the selected approach".

According to W.E. Mackey "A method determines when and how much is taught (selection), the order in which it is taught (grading) and how the meaning and form are conveyed (presentation) and what is done to make its use".

According to Binning and Binning "Methodology should be conceived as a dynamic function of education and not as static aspect or the process of teaching".

There are various methods available; teacher is free to use the methods according to his own abilities, interest, experience, nature of topic to be taught and according to the students. We can classify the method into two broad categories: (a) Teacher-centered methods and (b) Pupil-centered method.

(a) Teacher-centered methods: It includes three methods as:
(i) Lecture (ii) Lecture-demonstration and (iii) Historical
(b) Pupil-centered method: It includes five methods as:
(i) Project (ii) Problem solving (iii) Assignment (iv) Heuristic and (v) Experimental /Laboratory method

Guiding principles for Selection of a Teaching method

The teacher should keep in mind these guiding principles while selecting teaching methods:

- The appropriate method should be selected to achieve the objectives of teaching science.
- The teacher should have proper knowledge of teaching methods.
- Teaching method selected by teacher should be based on an understanding of the students in the classroom.
- Before selecting teaching method, the teacher should take care of age, class and capability of the students.
- We should select teaching methods based on the realization that the word education is a " drawing out" and not a " putting in".
- Teacher should select teaching method which leads the pupils to a sense of achievement through interest and purpose.
- Teacher should select teaching method which stimulates the pupils to think and cooperate actively.
- Teaching method should be selected on the experimental nature of the method.
- Teaching method should be selected for creating the needs of individual differences.
- Before selecting teaching method, a teacher should check the availability of apparatus and materials in the school required in that particular method.

Various methods of teaching Science

The methods used for teaching of Science are given below:

- Lecture method
- Demonstration method
- Lecture-cum-demonstration method
- Observation method
- Discussion method

- Demonstration –cum-discussion method
- Supervised study method
- Assignment method
- Laboratory method
- Heuristic method
- Problem solving method or scientific method
- Experimental method
- Project method
- Inductive-deductive method
- Review method
- Tutorial teaching method
- Question-answer teaching method
- Role playing method
- Brain storming method
- Discovery method
- Sensitivity training method
- Independent study method

According to the Syllabus of **The West Bengal University of Teachers Training Education Planning and Administration** few Methods have been discussed as:

2.1 Lecture Method

Lecture method is the most commonly used method of teaching science. This is a teacher structured method, and the students are just passive listeners most of the time. It is most commonly followed in colleges and in schools in higher classes. In this method a lesson is taught in the form of speech or talk. The teacher delivers a lecture on a particular topic and the students keep listening in an idle manner. Since the students do not actively participate in this method of teaching so this method is a teacher controlled and information centered and in this method teacher works as a sole resource in classroom instructions. The students cannot be motivated to attain knowledge themselves and they cannot be made capable to make use of the acquired knowledge. By this method it is difficult to find out the extent to which the students have been able to learn. In this method, students are provided with readymade knowledge b the teacher and due to this spoon feeding the students lose interests and his powers of reasoning and observation get no stimulus. In this method the teacher goes ahead with the subject matter at his own speed. The teacher may make use of black board at times and may also dictate notes. This teacher oriented method in its extreme form does not expect anything from the students. If the number of students in a class is large, teaching resources are scare or a limited number of periods are available on the time table, lecturing may be the only alternative. **According to Carter Good's dictionary,** "an instructional procedure by which the lecturer seeks to create interest, to influence, stimulate, or mould opinion, to promote activity, to impart information, or to develop

critical thinking, largely by the use of the verbal message, with a minimum of class participation; illustrations, maps, charts, or other visual aids may be employed to supplement the oral technique". The lecture is an exposition of knowledge, facts, principles or other information which a teacher wishes to present to her/his students. In brief, a lecture means one person addressing many students.

Characteristics of a good lecture

The lecture becomes effective if a teacher note down following points while using the lecture method. In general the lecture is used for**:**

- **Introduction of a new topic:** It not only motivates the students but gives guidelines for the students on what is to follow.
- **Summarising a topic:** The lecture method is effective in summarising the lesson, as the points highlighted would help focus the attention of the students.
- **Supplementary information:** This method is invaluable in supplementing text-book information as a follow-up or prior to laboratory work and in presenting the finding of field trips and project work.

The success or failure of the class rests on presentation of the lecture. This requires the teacher to check on the following points.

- **Posture:** While addressing a group it is preferable to stand so that audience can very well see and listen to him. Besides, it is also most convenient to stand and manipulate the visual aids to be used.
- **Appearance:** Clothes should be neat and suitable for the occasion. Once should wear a confident and friendly look while lecturing as students are very susceptible to first impressions.
- **Manner:** To hold the attention of the group during the lecture a teacher required to be poised and courteous.
- **Gesture:** Actions and gesture must be natural and spontaneous. Mannerisms like playing with the chalk, or any other similar object should be avoided, as they are distracting and sometimes extremely annoying
- **Voice:** The tone of the voice can be accordingly altered to convey confidence emotion, emphasis and indignation. Pace and volume should also varied occasionally to avoid monotony.
- **Vocabulary:** it is best to use simple language avoiding jargons metaphors and slangs, which could be misinterpreted. Sentences should be kept short as far as possible.
- **Use of audio visual aids and blackboard:** a well planned lecture, divided into parts, highlights focal points and can improve the instruction value of the lecture. The use of visual aids should be planned and well prepared.

- **Time:** Time available must be used effectively, keeping in mind the students listening threshold. Thus, recapitulation should form a part of the lecture say, the last ten minutes. Questions should be encouraged, discussions conducted to make the class more interactive.

Advantages of the Lecture Method

It has the following advantages:

- It is highly efficient if teacher teaches in systematic and logical manner.
- The lecture is useful in imparting factual information in efficient manner to convey facts to students who have difficulty in reading their texts.
- It is quick, and a lot of knowledge can be imparted in quite a lesser time.
- It is convenient and easy and a teacher is free to develop his own style of teaching.
- The lecture helps to channelize the thinking of students in a given direction.
- It is quite economical method. It is possible to handle a large number of students at a time and no laboratory, equipment, aids, required. It is economical in terms of both money and time.
- In this method teacher can easily maintain the logical sequence of the subject by planning his lecture in advance. It minimizes the chance of any gaps or overlapping.
- Some of good lectures delivered by teacher may motivate, instigate and inspire a student for some creative thinking.
- Some abstract topics in science are best taught by the lecture method. The teacher, through fact, style and presentation can get her message through.
- It simplifies the work of the teacher. The teacher has to put in much less effort to prepare his lesson.

Limitations of Lecture Method

The limitation of lecture method are :

- Students' involvement and participation is nil or quite less.
- The lecture method is not very successful in imparting attitudes and skills, as it does not touch the effective and psychomotor faculties of the learner.
- Teacher needs a lot prior knowledge to prepare a lecture.
- Students' previous knowledge or entry behaviours are usually not taken into consideration.
- Developing scientific attitudes are neglected.
- This method is not suitable and unpsychological for smaller classes.
- The students are not motivated towards learning.
- It is an undemocratic and authoritarian method in which students depends only as the authority of the teacher.

- In this method there is no place of 'learning by doing' and thus teaching by this method strikes at the very root of science.
- It does not cater to the individual needs and differences of students. It does not provide for corrective feedback and remedial help to slow learners.

Suggestion for the improvement of Lecture Method

The teaching by lecture method can be made more effective using following suggestion:

- It is wise to have note (in points) available while lecturing for ensuring correct sequencing of ideas and figure, but word by word reading from notes should be avoided.
- Make use of the black-board where and whenever required.
- Lecture can be improved by adding Teacher-Learner Interaction (TLI) and Learner-Learner Interaction (LLI) into it.
- Proper teaching aids should be used.
- More stress should be laid on the principle of generalization.
- In order to keep them active, questions should be put up to the students from time to time.
- The students should be given work to do so that they make use of their previous knowledge and acquire more knowledge on basis of their hard-work and experience.
- The lecture should be delivered slowly in an attractive tone in order to amuse and maintain the interest in the students.
- At the end of the lecture, opportunity should be provided to ask questions and to answer questions to make sure that the salient points have been understood by the students.
- Along-with the lecture method practice in note-taking should be given to students of higher secondary stage.

After discussing various advantages and limitations of lecture method it can be summarized that this method may be suitable for teaching in higher classes, where we aim to cover the prescribe syllabus quickly. In these classes this method can be used successfully for imparting factual knowledge, introducing some new and difficult topics, make generalization from the facts already known to the students, revision of lessons already learnt etc. This method of teaching can be made beneficial if the teacher encourages his/her students to take note during the lesson. While delivering his/her lesson the teacher may see that the lesson is delivered in good tone, loudly and clearly. He/she should use only simple and understandable words for delivering his/her lesson.

2.2 Demonstration Method

In the field of Science the demonstration method is very important. In this method both the teacher and taught are active. The teacher makes a theoretical investigation in the class and proves it. The teacher performs the experiment while teaching and the students acquire

knowledge while careful observation of the experiment. The students also put forth queries doubts.

Advantages of Demonstration Method

It has the following advantages:

- This method is appropriate for small classes.
- The demonstration is conducted by the teacher so there is less breakage of apparatus.
- Less time consuming.
- Students learn by seeing.
- The sight and hearing sense of the students is more active.
- The students develop the power of observation, reasoning and thought.
- The students are able to understand the principles clearly and the knowledge acquired is permanent.
- The teaching effective even if the numbers of apparatus are less.

Limitation of Demonstration Method

The limitation of demonstration method can be as under:

- The students do not get a chance to perform experiments.
- Some students are not able to observe properly.
- Sometimes the teacher is not able to perform the experiment properly and this creates a lot of doubts about the subject in the mind of the students.
- By this method only general knowledge about science can be demonstrated.
- It fails to impart training in scientific attitude.

Suggestions for the improvement of Demonstration Method

The teacher by demonstration method can be made more effective using following suggestions:

- The teacher should practice performing the experiment himself prior to demonstration before the students.
- The articles required for the demonstration should be kept on the demonstration table.
- The aim of the demonstration should be started before the students clearly.
- The students should have previous knowledge of the experiment to be performed, the articles, and apparatus being used so that the students do not have problem in understanding the demonstration.
- All experiments should be performed in front of the students. The place for experiment should be such that all students are able watch it.
- The help of students should be taken during the performing of experiment and their doubts should be cleared simultaneously.

- The teacher should use the black-board and other teaching aids as and when required along with the demonstration.
- The teacher should emphasise on the correctness of the script of the observation.
- The apparatus should be cleared carefully and kept after the completion of the experiment.
- The teacher should use easy language during performance of the experiment.
- After the completion of the experiment the teacher should discuss the observation and result of the experiment.

Purpose of Demonstration

Demonstration method may be used in Science teaching in a number of ways. They are suitable for the following purposes:

- **Demonstration purposes at the start of a lesson or unit :** There are many Science demonstrations which when presented for the first time to a group of students will stimulate their interest and curiosity. For instance, Science teachers could demonstrate colour changes by phenolphthalein to introduce students to acid-base reaction.
- **Showing method and technique:** students need to learn how to use and operate Science equipment, as well as procedures to take accurate readings. A teacher could demonstrate how to focus a microscope, how to take readings, the least count, vernier reading coincidence and so on.
- **Applying a concept:** The application of concepts in daily life can be well understood if demonstrated, e.g. effect of water, air and sunlight on germination. The teacher should state exactly what it is that students should realize and demonstrate the application of the concept, principle or law.
- **Solving problems:** Demonstrations could help study and solve problems, e.g. effect of heat on different kinds of metals. Such questions can be best answered by a demonstration. These situations require a certain amount of versatility on the part of the teacher.
- **Reviewing ideas:** Demonstrations can be used as a review technique while culminating a unit. They can be used to reinforce important ideas that were dealt with in class and help to summarize key points. A teacher can set up an experiment and ask review questions as the experiment is in progress. The students will be able to clear up the doubts which might have risen at this stage.

Planning a demonstration

An effective demonstration requires methodical planning by the teacher. The important points to be noted are as follows:

- The need and relevance of the demonstration.

- The objectives of the demonstration.
- Mastery of subject matter.
- Lesson notes including a list of principles to be explained and the questions to be asked in class.
- Thorough rehearsal of experiments before the class.
- Proper arrangement of apparatus on the demonstration table.

Criteria for a good demonstration

A successful demonstration will have the following criteria:

- The demonstration should be visible to all and the set up should be at a good height. Students should be seated either in gallery type classrooms or be allowed to come near.
- The apparatus used for demonstration should be larger in size.
- A blackboard behind the demonstration table will facilitate summarising the related principle and key concepts.
- The lighting and ventilation should be adequate and allowances must be made for glare etc.
- Rehearsal is necessary prior to a demonstration so that the teacher becomes well versed in handing the apparatus.
- The pace of the demonstration should be accurate, neither too fast nor too slow. This helps students to follow the demonstration carefully.
- Apparatus should be arranged in proper order, so that the teacher does not flounder. For instance, or right-handed teacher may prefer to keep the used apparatus on the right hand side.
- The teacher should make allowances for seasonal variations, power cuts etc. while planning her experiments.
- For recoding the data the students should be given sufficient time.
- The teacher should enliven her demonstration by asking suitable reflective type questions.
- Emphasis should be given to the major points in the demonstration; so that students are aware of the objectives of the demonstration.

2.3 Heuristic Method

The term “heuristic” refers to Armstrong who was the exponent of this strategy. It is based on the psychological principles of ‘trial and error’ theory. Logical and imaginative thinking are perquisites for this type of teaching strategy. It is an economical and speedy strategy. Heuristic is derived from a Greek word ‘HEURISKIN’ meaning ‘discovery’. Heuristic method was discovered on the idea that by placing a student in the position of a discoverer, he would learn much more than being merely told about things. The credit of discovering this method goes to

the professor Armstrong, who was of the view that information of scientific facts and concepts cannot be imparted properly through lectures or through written matters in the form of text-books. He was of the opinion that students should be given opportunity to gather scientific information on their own effort. Through this method, students are made active independent enquirers and they are indulged in various activities through which important scientific information can be gathered. Thus, they become active participators instead of passive recipient of the knowledge with the help of this method.

Meaning and concept

A problem is placed before the learners and they are asked to find the solutions of the problem through various literacy means, like library, laboratory and workshops etc. teacher's role is to initiate the learning and pupils are active throughout the learning process. By using their creative thinking and imaginative power, they try to find out relevant solutions based on some logic. They learn by self-experience. This teaching strategy is focused on:

- To develop problem-solving attitude.
- To develop scientific attitudes towards the problem.
- To develop power of self-expression.
- To encourage learner to himself as much as possible.

When Heuristic method is being used by the teacher, then each student is provided a sheet of instructions and they are required to perform the experimental works which are related to the problem provided to them. By following the instructions provided in the written form, students perform the experiment. Teacher keeps on guiding the students for conducting the experiment properly from time to time. Whatever students do, they keep note of them in their note books. After making experiment, they also derive conclusion from experiments and suggest the method by which problem can be sort out.

In the words of **Prof. Armstrong**, "Heuristic method is a method of teaching which involves our placing the students as far as possible in the attitude of a discoverer."

Principles of Heuristic Method

The Heuristic method is based on the following principles:

- Principle of freedom
- Principle of experience
- Principle of activity or learning by doing
- Principle of purposefulness
- Principle of logical thinking
- Principle of play way
- Principle of individual work

Role of the Teacher in Heuristic Method

For the Heuristic method to be fruitful, the teacher should play the following role:

- The teacher should help the students search for a suitable problem. Here the teacher should keep in mind the age, ability and level of the students, along with the facilities available.
- He should be a man of knowledge to give references etc.
- The teacher should act as a guide and instructor to the students providing them with sufficient background information and help to get students going.
- Detailed instruction sheets should be given to the students.
- He should provide an atmosphere for freedom in the classroom in order to encourage self-development, spontaneity and self-expression.
- He should be adept in the art of questioning and should encourage the students to ask questions.
- The teacher should help in developing values and attitudes consistent with science, by allowing freedom of thought and action.
- Arrangement for supplementing the students' knowledge should be made by the teacher be it library facilities or field trips.
- A gifted teacher should help the students draw inferences from their experiments and observations.

Advantages of Heuristic Method

Following are the advantages of this method:

- It helps in achieving cognitive, affective and psychomotor objectives i.e. it helps in all round development of the child.
- Students are put into the situation to learn by self-experience. It certainly develops self-confidence in the learners.
- It helps in developing scientific attitude and creativity in the learners.
- Teacher encourages the learners to explore the environment in search of the solution of the problems. By doing so, some new knowledge is discovered by them.
- Teacher is always ready to provide individual guidance regarding the solution of the problem. Thus, interaction between the teacher and the learner takes place in cooperative and conducive environment.
- The method lays stress on individual practical work, careful observation and independent thinking which makes a child self-reliant.
- The Heuristic method is based on the important psychological principle of learning by doing.
- Individual differences can be catered to, as each student can work at his pace.

- Students develop research skills, including setting up and fitting apparatus conducting experiments; habits of neatness and patiently attending to details are acquired.
- It develops in the student a habit of diligence.
- In this method most of the work is done in school and so the teacher has no worry to assign on check home task.
- In this method the relation between the teacher and the taught becomes more intimate and healthy.
- The students develop interest and capability to labour harder.
- This method makes them exact and brings them closer to truth.
- The knowledge obtained is more stable.
- This method prepares students for life.

Limitations of Heuristic Method

Following are the limitations of this method:

- It cannot be used at primary level of education.
- Higher intelligence and divergent thinking is required in the learners. But, there are some students who are below average and fail to succeed in discovering the solutions of the problems. It frustrates them.
- In the sense, none of the teachers have patience for providing individual guidance to the learners. And learners, too, feel hesitation to approach the teacher for seeking his help.
- Suitable text-books are not available.
- Practical problem like time tabling can creep in, making this method not quite suitable for the school.
- As a lot of experimentation is done, it implies that suitable infrastructure is needed to follow this method. Hence it can prove costly.
- The pace being slow the whole curriculum cannot be completed in a fixed time period.
- For this method, a good laboratory and a good library are required.
- It is a long and time consuming method and so it becomes difficult to cover the prescribe syllabus in time.
- Evaluation of learning through heuristic method can be quite tedious.
- Sometimes experiments are performed nearly for sake of doing them.
- The stress is more on skills than on knowledge. Hence the heuristic method could lead to an imbalance in learning, as knowledge is of secondary consideration.
- It is difficult to impart education to larger groups through this method.
- The students find it difficult to draw conclusions.
- The gradation of problems is a difficult task which requires sufficient skill and training.

Suggestions for the improvement of Heuristic Method

Following are the suggestions for the improvement of this method:

- There can be number of solution for a problem. So, it is the teacher's duty to provide guidance to the learners to select the most relevant solution of the problem.
- Problem should be related to the course and curriculum and a definite time period should be allotted to the learners to finish their research work.
- Students' abilities, capabilities, interest and choice of the subject should be taken into consideration in allotting the problems.
- There should be eligibility criteria for providing the problems.
- Heuristic method should be realistic.
- Few selected lessons should be taught by this method instead of the whole curriculum.
- It can be practicable in middle and high classes because they have acquired some knowledge to understand the common principle and material used in science.
- A well-equipped laboratory is also essential.
- It may be suggested that a heuristic approach must be prevailed for teacher of science in our schools.
- By heuristic approach we mean that students be not spoon fed or be given a direction rather they be given opportunities to investigate, to think and work independently along with traditional way of teaching.

2.4 Laboratory Method

Science subject should be learned through laboratory method. For teacher this subject, the laboratories are a must. The laboratory makes teaching of science more meaningful and interesting. In the laboratories the students learn about facts and laws of different branches of science and check their truthfulness and learn to make practical use of them. In this method the student becomes very active and learns himself. The student finds the answer to curriculum related problem under the guidance of the teacher. He himself notes down the figures of his observations and on the basis of calculations, draws conclusions.

The first function of the enquiring laboratory is the replacement of illustrations only of conclusion by illustration of problem situation. And it displays the phenomenon which gives rise to problems. These circumstances are surrounding the acquisition of data for solving this problem and the difficulty of working with and among these circumstances.

The second method for enquiring laboratory is to provide occasions for an invitation to the conduct of miniature but exemplary programmes of enquiry. The enquiry laboratory method is characterized by three general features. It erases the artificial distinction between classroom and laboratory, between mind and hand. One of the important functions of laboratory method is depending of the students, understanding the scientific concept and application, closely related to their own natural environment. Learning by doing is one of the cardinal principles of teaching science. The things learned by the students for purposeful activities or permanently affixed in the

mind of the pupil. Truth of the statement made by the teacher or written in the books when they experimental collaboration or without experimental experiences remains superficial, hazy and imperfect.

Activities in the Laboratory Method

- Collection of insects and preserving them.
- Collection of seeds, fruits, roots, animals and specimen micro plants and micro animals.
- Preparing specimens of the transverse sections of root, stem and leaf.
- Prepare slides.
- To set an experiment to observe respiration in plants and prepare the apparatus.
- To arrange for aquarium, terrarium and vivarium.
- Collection of useful plants and animals.

Advantages of Laboratory Method

This method of teaching has the following advantages:

- In this method the student performs the experiment in a laboratory and on the basis of the experiment he attains practical knowledge from theoretical knowledge.
- The student learns from his experiences. He develops the power of thinking, observation and decision-making.
- The students develop self-discipline and self-confidence.
- The students understand the topic clearly and easily.
- Favourable atmosphere is created for science teaching.
- Working collectively they develop the spirit of sociability.
- In the laboratory, all apparatus and material is available for the experiment, thus the time is not wasted in doing the practical and the breakage of apparatus is minimized.
- Helps in developing the habits of self-study.
- This is natural method of exploration. The children in order to acquire the knowledge and perform the practical with great joy and enthusiasm.
- Individual attention can be given to the students. Their weakness can be identified and proper help can be given.

Limitations of Laboratory Method

This method of teaching has the following limitations:

- This method requires a number of apparatus and laboratories. In places where these are not possible this method loses its importance.

- In this method the students are to be checked and proper instruction should be given or this method becomes mechanical. If proper instructions are not given a lot of time will be wasted by the students.
- Individual attention cannot be paid to classes with large number of students.
- Lot of time is required to attain a small amount of knowledge. Thus, for a vast syllabus this method is impractical. This method involves a lot of money and strength.
- Due to financial constraints, schools are not able to adopt this method.
- Not fit for small students.

Suggestions and Applications

This method of teaching has the following suggestions and applications:

- First of all the students should be given 'Laboratory Instructions' in the science laboratory.
- The teacher should see to the availability of apparatus, supervision during experiment and alertness towards cleanliness.
- Students' co-operation should be sought in the laboratory work e.g. distribution and collection of apparatus.
- The students should be given knowledge about the apparatus and the precaution to be taken while handling it.
- The teacher should put up questions between the practical to make the subject clearer.
- The students should develop he habit to draw the diagram side by side for identification.
- The laboratory should have a 'First Aid Box' to deal with any emergency in case of accidents.
- The teacher should study the complete syllabus and the text-books before preparing list for purchase of apparatus and then buy it.
- There should be a fixed place for each item in the laboratory.
- All the articles should bear labels in the laboratory. Old worn-out and defective apparatus should be replaced or rectified.

Thus, we see that practical works provide an activity which can be profitable and emotionally satisfied. Acquiring scientific knowledge and scientific outlook can be achieved only through practical works in the laboratory. Pupils get a good deal of training in attending the problem in scientific way. Good habits like cooperation, resourcefulness, initiative, self dependents, self-reliance, nature applicable in a daily life of the peoples. The achievement of modern science is mainly due to application work should form a permanent feature in any science course and the primary objective in determining a technique of instruction is to provide a maximum pupil activity. Laboratory method in all form helps in the achievement of the aims in science teaching which in turn help in the future development in the field of science.

2.5 Project Method

The project is defined in Oxford's Advanced Learner's Dictionary as a plan of action. It usually involves a task or problem, calling for constructive thought or action or both on the part of the student. Project method of teaching has evolved from the philosophy of pragmatists. It is experience-centered strategy related to life-situation. This teaching strategy focus on-to socialize a child and to achieve cognitive, effective and psychomotor objectives. This method was given by Dewey the American philosopher, psychologist and practical teacher. The project method is a direct outcome of this philosophy. The method of teaching gives more importance and recognition to the group activity.

Definitions of Project

"A project is a unit of activity in which pupils are made responsible for planning and purposing." ***Parker***

"A project is a problematic act carried to completion in its natural setting." ***Stevenson***

"A project is a whole-hearted purposeful activity proceeding in a social environment." ***Kilpatrick***

"A project is a bit of real life that has been imparted into school." ***Ballard***

By analysing these definitions, we see that a project has some purpose and there is planning to achieve that purpose which is achieve in social, real and natural situations created in the school.

Thus, it can be said that a project is a special kind of experience which is outcome of a desire of the students. Therefore, teaching by this method is based upon the use of desire of the students. Project method can be best explain through the phrase 'Learning by Living'. This phrase clearly explains the fact that human beings are social animals who cannot learn gain any kind of information by living in isolation. They always learn better in a group or society in which they are being placed. If any human beings intend to live harmoniously in society then he should be provided with well-balanced opportunities in schools and education institutions to solve out similar kind of problems which he usually face in his real or actual life.

Human life is full of projects, and all of us make different kinds of attempts to carry out these projects successfully. This method is designed on the idea that gap between social life and home life of the students should be bridge down. Such kind of atmosphere should be created in the schools in which students feel themselves in a small society. Under this method, around a central theme, connected facts are being develop, which can be in the form of scientific principles or facts.

Under this method, a suitable project is being picked up by the students, which they are required to complete in a cooperative and natural way. Generally such projects are inspired by needs and problems which students encounter in their day to day life. Students try to solve these problems through advice and guidance of the teacher.

Students are required to perform various kinds of activities while planning and executing the project in reality. As a result of felt needs of the students, what they learn through this method comes in a natural way. Thus, it can be said that teaching conducted through this method is a kind of incidental learning where teaching is undertaken as a result of mere coincidence in a very informal way.

Principles of Project Method

This teaching method is based on the following principles:

- **Principle of Utility:** Choose those projects which are closer to the social life.
- **Principle of Readiness:** Involve the learners in finding the solution of the problem with their active participation.
- **Learner by Doing:** Learner performs certain tasks and experiences new things. This adds to his knowledge and result in learning.
- **Principle of socialization:** It develops the feeling of cooperation and group work.
- **Inter-disciplinary Approach:** To involve the knowledge of different subjects in solving the social problems.
- **Learning by Living:** Students learn how to live together by performing tasks together in group.
- **Principle of Freedom:** Students are given full freedom for selecting and completing their project.
- **Principle of Living:** Learner performs so many activities for completing any project.
- **Principle of Purpose:** Every project has some purpose and students complete the project to fulfill the purpose.
- **Principle of Reality:** Every project is a replica of real object. It gives the complete idea of real object.
- **Principle of Experience:** Learner gains various experiences by doing project.
- **Principle of Correlation**: Students learn to correlate various things while doing any project.
- **Principle of Interest**: It develops interest among students towards teaching-learning process. Students can utilize their leisure time in a proper manner.

Types of Project Method of Teaching

Kilpatrick has classified the project method in four types:

- **Constructive:** when learners have to construct some things related to social life, e.g. charts, models, maps, parcels etc.
- **Artistic:** These project are generally allotted in the aesthetic fields of life e.g. in music, drawing, painting, art and culture.

- **Problem-solving:** these projects are given to solve the problems related to any life-situation or related to subject, e.g. problems related to food and nutrition, improvement in health etc. these general problems if solved will make a child efficient for social-life.
- **Group-work:** A team of students is assigned a work to be performed, e.g. to develop a garden in the school.

There are four basic elements of this teaching strategy which make it purposeful.

- Spontaneity
- Purpose
- Significance and
- Interest or motivation

Steps Involved in the Project Method

This method involved the following steps of project method:

- Providing a situation
- Choosing and purposing
- Planning of the project
- Executing the project
- Judging the project
- Recording the project

Providing a situation

A project should arise put of a need felt by pupils and it should never be forced on them. It should be purposeful and significant. It should look important and must be interesting. For this the teacher should always be on the look out to find situation that arise and discuss them with students to discover their interest. Situation such method may be included by talking to students on the topics of common interest.

Choosing and purposing

The children should be tempted to choose a project. While choosing the project the teacher should bear in mind that it should be of real needs pupils. The purpose of the project should be clearly defined and well understood by the pupils. A project which is very ambitious may prove to be a flop and a total waste of teacher and the student time. The points to be taken in consideration are: **(a)** the student's interest, **(b)** degree of complexity of project **(c)** time allotted to furnish the project and **(d)** availability of material resources.

Planning of the project

Planning in a project is very important for the success of a project depends upon good planning. The teacher should be actively involved in this stage in order to guide the students to choose the most practical plan of action: **(a)** the students should themselves do the planning with the teacher as a guide; **(b)** discussion may be held among the student; **(c)** after a discussion, the best of plans is agreed on and **(d)** the planning is recorded in their project book.

Executing the project

The teacher assigns work to the various group members according to their interest and abilities. Each member of the group should be actively involved in the execution of the project. In this step: **(a)** the work assigned by the teacher to each group is further subdivided by the students among themselves thus distributing the various activities and duties, **(b)** the students collect information, visit various places, keep accounts and perform a variety of activities.

Judging the project

The evaluation of the project should be done both by the pupils and the teacher. Pupils should estimate the qualities of what they have done before the teacher gives his evaluation. The evaluation of the project has to be done in the light of plans, Difficulties in the execution and achieved results. Let the students have self-criticism and look through their own failings and findings. This step is very useful because as a result of the project, the pupils can know the values of the information; interest, skills and attitude have been modified by the project.

Recording the project

The students keep a complete record of work including the choice of the project, the planning methodology, the discussions held and duties assigned. Also, references and books consulted and readings taken, difficulties faced, guidance sought and so on.

Format of a project report

The following format of a project report can be adopted:

- **Title:** A brief title should do, if accuracy requires more than a few key words, a subtitle may be considered.
- **Abstract:** This is a brief summary of the entire project highlighting the objectives, method used and conclusions arrived at.
- **Introduction:** A description of the topic being studies, along with relevant background information is given here. A clear statement of the purpose, scope and the method of the study
  should be included.
- **Materials and methods:** A description of the equipment/chemicals, method and procedures used and experiments performed is given.
- **Observations:** The recorded observations and data are noted under this section.

- **Results:** The findings from the study are given in detail in this section. Students can be taught to interpret their findings and comparing their results with other workers in the same field.
- **Appendix:** Students can insert any supplementary information in this section.
- **Bibliography:** A list of references is given to help other students to follow up if they so wish.

Criteria of a good project

Criteria of a good project are the following:

- A project should be purposeful and complete in itself. It should be useful and practically application to the daily life of the students with clear and well-defined objectives.
- The learning activity is life-like, purposeful and natural.
- The learners plan and direct their own activity.
- The project should be timely.
- The project should be challenging.
- The project should be feasible.
- The level of complexity of the project is of prime importance for its success or failure.
- The project should be aimed at problem-solving.
- The learning experiences gained during the progress of the project should be useful.
- There should be full freedom for the students to work of their own accord.

Role of the Teacher in Project Method

The teacher should assume the following role in accomplishment of project goals:

- He is a guide, friend and philosopher.
- He helps the student in solving their problems just like an elder brother.
- He encourages his students to work collectively, amicably in the group.
- He also helps the students to avoid mistakes.
- He makes it a point that each member of the group contributes something to the completion of the project and in this process helps the shy and weaker students to work along-with their classmates.
- If the students face failure during execution of some steps of the project the teacher should only explain to his students the reasons of their failure and should suggest them some better methods that may be used by them next time for the success of the project.
- During the execution step teacher also learns something.
- Teacher should always remain alert and active during execution, step and see that the project teacher should maintain a democratic atmosphere.

- Teacher must be well read and well informed so that he can help the students to the successful completion of the project.

List of Some Project for Science Class

Here are given some project for a Science class:

- Flower and fruit
- How plant reproduce
- Our food
- Study of rocks
- Our atmosphere
- Water
- Air
- Ways of preserving food
- Butterfly and moths
- Maintaining an aquarium
- Generation of electricity
- Recording and reproduction of sound
- Telephones
- Crystal set
- Wireless transmission

Advantages of Project Method

The advantages of project method of teaching science are as follows:

- It helps in developing social norms and social values among the learners.
- It provides invaluable opportunities for correlation of various elements of the subject matter and for transfer of training or learning.
- It helps in growing knowledge very effectively as a result of their close cooperation on social participation in the spirit of democracy.
- As students get proper freedom to execute the project in accordance with their interest and abilities, because of which they get their psychologist needs satisfied to considerable extent.
- This method is not only subject centered, but due to importance is being provided to the students also. Students are permitted to choose projects on their own, as result of which they make use if their abilities to maximum extent.
- Through this method, students are provided with various opportunities by which they can satisfy their interests and desires.

- Habit of critical thinking gets developed among the students through this method. Not only get this, an urge to make use of scientific methods to solve various problems also developed among the students through this method.
- With this method, students get the ample chances in which they can develop coordination among their body and mind. Through this method, teacher can lead a well-balanced development of the students.
- As students gain knowledge directly through their own efforts, thus, they acquire permanent kind of information, which is retained by them since a long period of time.
- Mostly the projects are undertaken in classroom as classroom assignments, because of which load of home work from the students get reduced to considerable extent.
- This is based on 'learning by doing'.
- This is a psychological method.
- The students have to perform mental and physical work thus they develop the quality of dignity of labour.
- A project affords opportunity to develop to keenness and accuracy of observation and produces a spirit of enquiry.

Limitations of Project Method

This method has the following limitations,:

- The project cannot be planned for all subjects and whole subject matter cannot be taught by this strategy.
- It is not economical from the point of view of time cost.
- It is very difficult for a teaching to plan or to execute the projects to the learners and supervise them.
- Such method can only be proving successful if the teacher is highly knowledgeable, alert and exceptionally gifted.
- Systematic and adequate learning is not provided by this method, as it is a method of incidental learning. Thus, through this process, it is not possible to treat. The curricular areas in systematic and orderly manner.
- Generally it is found that teachers do not possess much information regarding the manner in which his method should be used as a result of which they hesitate from using this method, as a result of which, its utility remains more or less limited to negligible extent.
- This method leaves a gap in pupil's knowledge.
- Sometimes the projects may be too ambitious and beyond pupils capacity to accomplish.
- The education given by projects is likely to emphasise relationships in breadth than in depth.
- Text-books and material written on these lines are not available.

Suggestions for using Project Method

This method has following suggestions:

- This method should be not used an independent teaching strategy but as a supplementary teaching technique.
- Teacher should try to utilize the inexperience and waste projects to prepare models etc.
- To avoid the problem of supervision, teacher may appoint a leader to each group of students.
- Teacher should fix a time limit for each project.
- Project should have definite objectives.
- All students should be given responsibilities according to their capabilities.
- All figures should have graphical representation.
- The students should be given the freedom to interact among themselves.
- The charge of disorganized and irregular study can be removed by making a provision in the time-table for formal class teaching of subjects.
- The problem of expenditure can be easily solved by undertaking some such projects in which we can earn something or in other words the project should be made economically self-sufficient.

2.6 Computer Assisted Instruction (CAI)

The term CAI has been defined in different ways:

Use of a computer to assist in the presentation of instructional materials to a student to monitor learning progress, or to select additional instructional materials, in accordance with the needs of the individualized learners.

- International Dictionary of Education (1985)

Instruction in which a computer is used to present substantial amounts of learning material to the student, it often represents an auto, instructional technique enabling students to progress at their own individual rates.

- The Concise Dictionary of Education (1982)

Computer Assisted Instruction (CAI) is one of the new approaches of instruction. In CAI, there is a flow of information and interaction between the computer and student. The computer delivers instructions directly to students and allows them to interact with it through the lesson programmed in the system. A computer provides feedback to the learners on the basis of his performance. The computer act as a teacher to the student, the computer performs the teaching-learning functions through different instructional modes.

Modes of CAI

The various ways in which CAI can be used are called modes. The common modes of CAI are

1 Drill and practice – A series of exercises is presented to a student by the computer. The student gives responses. The responses are processed by the computer and accordingly new activities are designed. The computer can create exercises avoiding repetition. Thus endless exercises can be provided by the computer for drill and practice. Long answers or responses are generally avoided.

2 Tutorial – The topic is generally divided into a sequence of short sections in Skinnerian Frames. The programmed text presents a number of problems for determining student's mastery of a particular frame and deciding the branching requirement for the next step. In tutorial mode each learner can be diagnosed at every small step and be led to anew path or branch depending on his requirements.

3 Conversation or Dialogue – Both the teaching system and the learner can ask question and answer them, complex interactive dialogue can be designed on the basis of deep questioning technique and multifaceted analysis of the student's responses.

4 Instructional Games – This is one of the most effective technique of CAI Game can add new dimensions to classroom teaching if they are carefully designed and evaluated to achieve a set of teaching objectives. Games are encouraging co-operative efforts where to or more students play against the computer. This may help to develop self-esteem of students who are otherwise unsuccessful in the classroom. Gaming involves an element of competition motivating learners to approach problem situation with enthusiasm.

5 Simulation - Simulations present real life-like situation that allow students to learn through experience and to take risks without suffering the consequences of poor choices. Computer can be used to simulate a real life system by following a set of rules which approximate the behaviour of the system.

6 Databases - Learning very often takes place through exploration of resources materials and utilization of libraries. The power of the computer to store, retrieve and process information is used to help the student to browse through the materials.

7 Problem Solving – To solve a problem, students define it and state the desired end result. What must take place in between is a logical progression of steps to reach the end result. The interactive nature of CAI helps the students to attempt problem in a logical and orderly manner.

8 Discovery – This mode uses inductive approach to learning where in the problems are presented and the learner solve the problem through trial and error.

9 Narrative or presentation Mode – The computer screen is used to present materials to students in a form sometimes referred to as an electronic chalkboard. Along with normal verbal presentation, movement and animation can be used with colors and music.

Advantages of CAI:

- Stimulates learning
- Provides immediate feedback on tests results
- Enables students to practice test items until their answers are correct
- Engages the interest of the student and motivates him/her to learn
- Enables the student to learn at his/her own pace and at his private environment
- Increases students' independence for studies

Disadvantages of CAI:

- A programmer cannot cater for every possible response and may give unexpected and unhelpful responses to unusual input.
- A few students are intimidated by the strangeness of a computer terminal.
- Packages can become boring if a student is alone at a terminal for too long. *Most packages should run for an hour or so.*
- *A package will not be appreciated unless it has a perceived goal and will not be considered important unless it is integrated into a course to the extent of being assessed by a teacher*.

The Teacher and the CAI

Computer-Assisted Instruction is not to exclude the teacher from the classroom. Machines mean relief from the more mechanical aspects of the teacher's work. Teacher need no longer be 'talking books' or 'paper correcting automations'. They can hereafter work in area like evaluation, planning, curriculum revision, guidance and human relations. Although we cannot forecast the areas wherein computers may be helpful in future, the possibilities of their effective use in the educational scene are enormous.

In addition to machine intended for auto instruction, educational technologists also recommend system approach facilities which represent an integrated and programmed complex of media, machinery as well as personnel whose components are structured as a single unit with

a time schedule and sequential phasing. The system approach utilizes the principle of 'cross media approach' in instruction, with a variety of related material reinforcing the instructional effect of each other. Many such media-machine system facilities have been developed in the West for different purposes. For example, 'the systems concept reading unit contains' a tape recorder, a controlled reader, headphones, tapes, filmstrips, books, etc. needed for a reading programme, Electronic 'Learning Laboratories' with similar hard and software, Dial access retrieval systems, Multimedia consoles for class use and similar machine system are also available. The classroom teacher can build up instructional system facilities for his use around important subject content units using the available facilities and innovating needed media.

2.7 Problem Solving Method or Scientific Method

The method or procedure which the scientists use in the pursuit of the science may be termed as Scientific Method (Sharma, 2009). A 'Scientific Method' is a method which used for problem solving a problem scientifically. It is also referred to as 'the method of science' or 'the method of scientist'. Scientific method is one of the methods for discovery learning. Training in scientific method necessitates the encouragement of innovative demonstration and laboratory experiment. It consists of systematic observation, classification and interpretation of data (Lundberg). Basically, it is a problem-solving method in other words it is a method of solving a problem scientifically.

According to **Risk**," Problem-solving method may be defined as planned attack upon difficulty or perplexity for the purpose of finding a satisfactory solution." Risk further elaborates that problem-solving teaching procedure is process of raising a problem in a minds of students in such a way as to stimulate purposeful, reflective thinking in arriving at a national solution.

According to **Ross**, "Problem-solving method is an educational device whereby the teacher and pupils attempt in a conscious, planned, purposeful manner to arrive at an explanation or solution to an educationally significant difficulty."

According to **Yokam, Gerland and Simpson**, "Problem-solving is a method in which a person use his ability to solve the problems which confront him, enables a man to exercise control over his activities and his environment. Without it he is at the mercy of nature and cannot make intelligent social progress."

It is obvious that learning science is the more than just accumulating knowledge about the science. The method of discovery learning involve the students in exploration, questioning, problem-solving, inductive reasoning, invention and labeling. However, a guided approach to discovery learning can reduce error and time. It is important that the both the teacher and the students be aware of the steps of scientific method or problem-solving method.

Step in problem-solving method or scientific method

The following steps should be followed to solve a problem. Dewey has outlined this method in the following series of steps:

- Identifying and defining the problem
- Formulating the hypotheses
- Testing the hypotheses by collecting and evaluating the data
- Interpreting the results
- Drawing conclusions

Identifying and defining the problem

Student come across several situations where they can apply skills and knowledge to a problem that motivates them to participate exploring. These problem can be stem from daily life or from the background literature on some topic or from the place of the work of the students. The students define their problem in a concise, definite and clear language. The teacher should help the student in stating the problem. The student may be asked to write down the statement of the problem in the light of above criteria and then read it in a class criticism and discussion. The most appropriate statements should be accepted.

Formulating the hypotheses

The student should focus on hypothesizing the relationship between two or more variables or difference between two treatments. A review of the literature would give student more content information; various possible causes of the problem may be listed. These possible causes are the hypotheses or 'educated guesses'. Next the students are asked to outline a laboratory procedure to test out their proposed solution.

Testing hypotheses by collecting and evaluating data

Students are permitted to enter the laboratory to conduct their tests and note down observations. The teacher's job at this juncture is to ensure that the students work carefully and collect accurate data.

Interpreting results

All inferences bearing on the data at hand must be considered tentatively. This phase of problem-solving demands an unusual amount of guidance from the teacher. Interpretation of data should be based on proper use of techniques and charts, graphs, tables can be used to record the data. At this stage, students can become careless in their work and it is an opportunity to develop skills in constructing tables and graphs.

Drawing conclusions

The students are asked to determine if their results substantiate the expected solution. Conclusions drawn on the basis of data should be accurately reported after proper interpretation. Findings should be reported concisely, and recommendations for further work should be mentioned. The students should be able to make generalizations and apply it to their daily life.

Factors influencing problem-solving

Ausubel identified several factors which influence problem-solving. Some of these are:

- Problem-solvers focus more on the problem on hand then other aspects.
- They are able to relate additional content information with the problem they are working on.
- Problem-solvers, besides being more persistent, possess self-confidence.
- They are objective in their approach to problem-solving.

Criteria for the selection of problems

The selection of a problem is very important in investigating thought process. The following criteria should be kept in mind:

- The problem should be stated in a clear and concise way using words and terms the students are familiar with.
- The problem chosen should be neither too difficult nor too easy. If possible the teacher should select problems based on the daily experiences of the children.
- The problem should preferable be a new one, though the children should possess all the basic

  information needed to solve the problem.

- Every child in the class should be able to solve at least part of the problem.

Advantages of problem-solving Method

Some of the advantages of this problem are:

- Students learn to find the solution of their problems themselves.
- They develop the power of observation and argumentation.
- It helps the students to develop reflective thinking and increases their intellectual potency.
- It helps students to develop the ability to sense the relevance of variables, make intuitive guesses and define problems concisely.
- It builds a mental attitude for effective learning based on critical thinking.
- It helps students to approach future problems with confidence in their abilities to seek out the solutions, patterns and relationships.
- They are familiar with the process of the collection of data, evaluation and drawing inferences.

- They are capable to generalise
- They learn to use old facts in new references.
- They develop a feeling of working together.
- This is based on "Learning by doing".
- This is a motivating method.
- It gives enough to students in techniques of information processing.
- It trains the students to identify and formulate scientific problems
- It provides the students training in the methods and skills of discovering new knowledge.

Limitations of problem-solving Method

Some limitations of this method are as under:

- It is time consuming process. Consequently, the teacher may not be able to complete the syllabus.
- It can never be a full-fledged method of learning science.
- It is not suitable for all students as it suits only bright and creative students.
- Majority of science teachers cannot implement it successfully because of this lack of exposure to such a method.
- Not all students are problem-solvers.
- The science curriculum cannot be organised according to the problems chosen.
- References and resource materials may be difficult to come by.
- Not all school laboratories are equipped to allow this method to be followed.
- This method requires gifted science teachers trained in the scientific inquiry approach, with not only tact and patience, but also research skills.
- There is always a doubt of drawing wrong conclusions.

Short Questions with Answers

Marks - 2

Q. Define Method?

Ans: According to dictionary "A method is a way of doing things. Method deals with how to teach. Thus method is an overall plan of teaching approach".

According to Anthony "Method is an overall plan for the orderly presentation of language material, no part of which contradicts and all of which is based upon the selected approach".

Q. Name any two Teachers centred Methods used in teaching-learning of Science.

Ans: 1.Lecture Method: This is the most dominant method today and is liked by most of the teachers. Though it is economical, it does not help in achieving the main objectives of Physical Science teaching.

2. Lecture-Demonstration Method: In this method teacher explains while performing the demonstration. This is in accordance with the maxims of teaching "From concrete to abstract" . The pupils are active participants in the teaching-learning process.

Q. What is Lecture Method?

Ans: Lecture method is the most commonly used method of teaching science. This is a teacher structured method, and the students are just passive listeners most of the time. It is most commonly followed in colleges and in schools in higher classes. In this method a lesson is taught in the form of speech or talk

Q. State any two features of good Lecture.

Ans: (i) Introduction of a new topic: It not only motivates the students but gives guidelines for the students on what is to follow.

(ii) Summarizing a topic: The lecture method is effective in summarising the lesson, as the points highlighted would help focus the attention of the students.

Q. Mention any four advantages of Lecture Method.

Ans: Following are the four advantages of Lecture Method:

- Lecture method is highly efficient if teacher teaches in systematic and logical manner.
- The lecture is useful in imparting factual information in efficient manner to convey facts to students who have difficulty in reading their texts.
- It is quick, and a lot of knowledge can be imparted in quite a lesser time.
- It is convenient and easy and a teacher is free to develop his own style of teaching

Q. Mention any four disadvantages of Lecture Method.

Ans: Following are the four disadvantages of lecture Method:

- Students' involvement and participation is nil or quite less.
- The lecture method is not very successful in imparting attitudes and skills, as it does not touch the effective and psychomotor faculties of the learner.
- Teacher needs a lot prior knowledge to prepare a lecture.

- Students' previous knowledge or entry behaviours are usually not taken into consideration.

Q. Name any four Pupil-centred Methods used in teaching-learning of Science.

Ans: (i) Project Method (ii) Problem solving Method (iii) Assignment Method and (iv) Experimental /Laboratory Method

Q. Name any four Traditional Methods used in teaching-learning of Science.

Ans: (i) Lecture Method (ii) Lecture cum demonstration Method (iii) Laboratory Method and (iv) Discussion Method

Q. Name any four Modern/Discovery Methods used in teaching-learning of Science.

Ans: (i) Scientific Method (ii) Project Method (iii) Problem solving Method and (iv) Heuristic Method

Q. What is Demonstration Method?

Ans: In this method both the teacher and students are active. The teacher makes a theoretical investigation in the class and proves it. The teacher performs the experiment while teaching and the students acquire knowledge while careful observation of the experiment. The students also put forth queries doubts.

Q. State any four merits of Demonstration Method.

Ans: Following are the four merits of lecture Method:

- This method is appropriate for small classes.
- The demonstration is conducted by the teacher so there is less breakage of apparatus.
- Less time consuming.
- Students learn by seeing.

Q. State any four demerits of Demonstration Method.

Ans: Following are the four demerits of lecture Method:

- The students do not get a chance to perform experiments.
- Some students are not able to observe properly.
- Sometimes the teacher is not able to perform the experiment properly and this creates a lot of doubts about the subject in the mind of the students.
- By this method only general knowledge about science can be demonstrated.

Q. What is meant by Heuristic Method?

Ans: A problem is placed before the learners and they are asked to find the solutions of the problem through various literacy means, like library, laboratory and workshops etc. teacher's role is to initiate the learning and pupils are active throughout the learning process. By using their creative thinking and imaginative power, they try to find out relevant solutions based on some logic. They learn by self-experience.

Q. Define Heuristic Method.

Ans: In the words of Prof. Armstrong, "Heuristic method is a method of teaching which involves our placing the students as far as possible in the attitude of a discoverer."

Q. What are the important roles of a teacher in Heuristic Method?
Ans: Following are the important role of teacher in Heuristic Method:

- The teacher should help the students search for a suitable problem. Here the teacher should keep in mind the age, ability and level of the students, along with the facilities available.
- He should be a man of knowledge to give references etc.
- The teacher should act as a guide and instructor to the students providing them with sufficient background information and help to get students going.
- Detailed instruction sheets should be given to the students.

Q. Mention any four advantages of Laboratory Method.
Ans: Following are the four merits of lecture Method:

- In this method the student performs the experiment in a laboratory and on the basis of the experiment he attains practical knowledge from theoretical knowledge.
- The student learns from his experiences. He develops the power of thinking, observation and decision-making.
- The students develop self-discipline and self-confidence.
- The students understand the topic clearly and easily.

Q. What are the important roles of a teacher in Heuristic Method?
Ans: Following are the important roles of teacher in Project Method:
The teacher should assume the following role in accomplishment of project goals:

- He is a guide, friend and philosopher.
- He helps the student in solving their problems just like an elder brother.
- He encourages his students to work collectively, amicably in the group.
- He also helps the students to avoid mistakes.

Q. Define Computer Assisted Instruction (CAI).
Ans: The term CAI has been defined in different ways:

"Use of a computer to assist in the presentation of instructional materials to a student to monitor learning progress, or to select additional instructional materials, in accordance with the needs of the individualized learners". **- International Dictionary of Education (1985)**

" Instruction in which a computer is used to present substantial amounts of learning material to the student, it often represents an auto, instructional technique enabling students to progress at their own individual rates". **- The Concise Dictionary of Education (1982)**

Q. Mention any four advantages of Problem solving / Scientific Method.

Ans: Following are the four advantages of Problem solving / Scientific Method:

- Students learn to find the solution of their problems themselves.
- They develop the power of observation and argumentation.
- It helps the students to develop reflective thinking and increases their intellectual potency.
- It helps students to develop the ability to sense the relevance of variables, make intuitive guesses and define problems concisely.

Q. Mention any four limitations of Problem solving Method.
Ans: Following are the four limitations s of Problem solving Method:

- It is time consuming process. Consequently, the teacher may not be able to complete the syllabus.
- It can never be a full-fledged method of learning science.
- It is not suitable for all students as it suits only bright and creative students.
- Majority of science teachers cannot implement it successfully because of this lack of exposure to such a method.

Probable Questions

Very short answer type questions **Marks - 2**

1. Define Method?
2. Name any two Teacher centred methods used in teaching-learning of Science.
3. What is Lecture Method?
4. State any two features of good Lecture.
5. Mention any four advantages of Lecture Method.
6. Mention any four disadvantages of Lecture Method.
7. Name any four Pupil-centred Methods used in teaching-learning of Science.
8. Name any four Traditional Methods used in teaching-learning of Science.
9. Name any four Modern/Discovery Methods used in teaching-learning of Science.
10. What is Demonstration Method?
11. State any four merits of Demonstration Method.
12. State any four demerits of Demonstration Method.
13. What is meant by Heuristic Method?
14. Define Heuristic Method.
15. What are the important roles of a teacher in Heuristic Method?
16. Mention any four advantages of Laboratory Method.
17. Distinguish between Demonstration Method and Experiment Method.
18. What are the important roles of a teacher in Heuristic Method?
19. Define Computer Assisted Instruction (CAI).
20. Mention any four advantages of Problem solving Method.
21. Mention any four limitations of Problem solving Method.

Short answer type questions **Marks - 5**

1. Distinguish between Teacher-centred and Pupil-centred approaches in Teaching Physical Science. Which approach is more appropriate in teaching Science in Indian schools?
2. What is meant by Project Method? Explain its various steps with suitable examples from Physical Science syllabus of West Bengal Board of Secondary Education (WBBSE).
3. Illustrate how Problem solving Method is useful for a Physical Science teacher?
4. What is Assignment Method? How far is the Method applicable in teaching of Physical Science in Schools?
5. Elaborate Lecture-cum-Demonstration Method by taking a suitable topic from Physical Science syllabus of WBBSE.
6. Huxley said "The great end of life is not knowledge but action" .Explain the saying and discusses the Scientific Method to reach this end.

Long answer type questions **Marks - 10**

1. What is meant by Method of teaching? Explain the criteria for selecting a particular Method for a Physical Science teacher.
2. Discuss advantages and disadvantages of the Demonstration method of teaching Physical Science in schools.
3. What is the importance of Lecture-cum-Demonstration Method in the teaching of Physical Science? Explain with examples.
4. What is CAI? Illustrate various modes of CAI with suitable examples from Physical Science syllabus of WBBSE.
5. What is Heuristic Method? What precautions should be taken by the teacher while employing this method in teaching of Physical Science?

Unit 3: Planning of Science Laboratory

3.1 Importance of Science laboratory
3.2 Organizing/planning a Science Laboratory
3.3 Equipment of Science Laboratory

The study of Science is not possible without a laboratory. Laboratory work can be used as a powerful learning resource of Science. **Laboratory work is based on the principle of learning by doing and it is an integral part of science education.** It helps in better understanding of various concepts of science and construction of knowledge. The first-hand experience obtained through experimental work imprints a permanent impression on the mind of the learners. It provides opportunity to the teacher to inculcate various process skills of science, viz. observation, classification, analysis of data, recording, inferring, generalising and communicating. Process skills so acquired help in developing interests, values, and spirit of inquiry that constitute scientific attitude. Students learn while handling, manipulating and innovating different types of equipment. It provides an environment to learners for exhibiting their qualities such as resourcefulness, initiativeness, orderliness, cooperation, and team spirit. Students enjoy working together with their peers with some freedom of action, having a feel of the excitement of the unknown and achieving a sense of discovery. Of course, learners cannot rediscover all of science; however, encouraging them to observe, investigate and think critically on a laboratory activity can facilitate them to construct some abstract concepts and principles of science, to awaken curiosity about the world around them and to gain a feel and appreciation of science. The kind of experience that is provided by the laboratory cannot be replaced by any other exercise. Well-planned laboratory experiences have great potential to attract our young generation into science courses. Performing experiments in prescribed fashion and just involving students in hands-on activities do not result in development of inquiry skills in Science.

Objectives of Laboratory work

Use of Science laboratory must be focused towards achieving following objectives:

Laboratory work facilitates in the development of (i) cognitive abilities, i.e. principles and laws discussed in the classroom may precede or follow the laboratory work or it may be carried out during discussion; (ii) process skills of Science; (iii) Scientific attitude; and (iv) understanding nature of Science.

3.1 Importance of Science laboratory

- In a laboratory the student performs the experiment and on the basis of the experiment he attains practical knowledge from theoretical knowledge.
- The student learns from his experiences. He develops the power of thinking, observation and decision-making.

- The students develop self-discipline and self-confidence.
- The students understand the topic clearly and easily.
- Favourable atmosphere is created for Science teaching.
- Working collectively they develop the spirit of sociability.
- In the laboratory, all apparatus and material is available for the experiment, thus the time is not wasted in doing the practical and the breakage of apparatus is minimized.

Opportunities to raise question, involving the learners in critical discussion, investigating their own questions and being flexible in the work should be facilitated in the laboratory. Inquiry can be broadly planned considering limited availability of time and crowded classrooms. It is to be kept in mind that emphasis should be given to the first five letters of LABORATORY rather than the last seven letters.

3.2 Organizing/planning a Science Laboratory

Science teachers must plan laboratory work well in advance making best uses of available materials and time. Proper planning of laboratory work is required in order to provide opportunities to all students to manipulate equipment and materials, interact and work collaboratively with peers in an environment where they feel free to investigate and find solutions to their inquired problems. You can think on the following points:

- ❖ Sufficient equipment and apparatus should be set up where a group of two–three students can work together. If sufficient number of apparatus required for one experiment or activity is not available in the laboratory, different experimental set-up for different groups of students may be planned.
- ❖ Laboratory equipment and experimental set-up should be tried out for their functionality before the start of laboratory period.
- ❖ Students should be involved in setting and checking up the equipment and apparatus.
- ❖ Pre-laboratory discussion with students becomes necessary in some instances. For example, you may feel that understanding of Wheatstone bridge principle is required to perform experiment on a meter bridge; knowledge of the principle of potentiometer is required before performing the experiment, etc. Pre-laboratory session is required for making students aware of the safety measures to be taken in the laboratory. They should be encouraged to identify their own problems and select their own procedure for laboratory activities. Pre-laboratory discussion can be very helpful for this purpose.

Students can relate applications of scientific concepts and principles in their everyday life by using everyday materials and can get more inclined to acquire inquiry skills. As laboratory work is an integral part of teaching- learning of science, laboratory activities should be interwoven with the teaching-learning of theoretical aspects of physical science. Laboratory work includes activities, experiments, demonstration by students and teachers and project work. A topic should be scanned beforehand to plan what kind of laboratory work can be carried out for its transaction. Students should be involved in the work of identifying, selecting and arranging for the materials required for performing various kinds of laboratory work. Questions and interest of

students should also be kept in mind in designing teaching-learning experiences in the laboratory. Involving students in planning of laboratory work encourages them to be more responsible for their work and conduct in the laboratory.

A teacher can plan on thinking along the following:

- Is the objective activity/experiment/project work clear to the students?
- How will I facilitate them to perform the experiment?
- Are materials/apparatus available in the laboratory?
- How will I involve learners in setting up the experiment?
- Have I performed the experiment myself to check the functionality of all apparatus?
- Is the procedure simple and can be performed within the allotted time period?
- How will application of their findings enhance their learning?
- How will I integrate the laboratory experiments with classroom teaching-learning experiences?

The learning experiences in the laboratory should provide some challenge to the students to learn. They get interested if they understand the purpose of the experiment and are made to realize the application of it to their everyday life.

Students can be involved in planning and organising various works of laboratory. Following guidelines for planning and organising experiments in Physical Science may be considered.

- It should be ensured that students have a sound theoretical knowledge required for handling the apparatus and performing the experimental work. For this, theory and practical teaching-learning situations should be properly integrated and coordinated.
- Students should come prepared for the laboratory work. They should be encouraged to refer laboratory manual and other supplementary materials. They should be facilitated to find answers to their own questions.
- Enough apparatus should be set up to provide opportunity to all learners on hand-on activities. It should be checked that the apparatus are in proper working condition.
- **During the laboratory work, extensive critical discussion on the theoretical aspects of the experiments with the students and continuous assessment of their performance are of utmost importance**. This helps the teacher to know their misconceptions and naive concepts and she can then facilitate them in the construction and reconstruction of their knowledge.
- A notice board to display safety rules of the laboratory, time-table, lists of experiments, group patterns, etc. can be maintained and kept up to date.
- Good discipline is necessary for smooth function of the laboratory work.
- Maintaining all possible standards of safety in the laboratory and inculcating safety conscious attitude in students are important.

- Safety kits such as fire extinguishers, sand bucket, rubber gloves, separate dustbins for dry and wet waste materials, etc. should be kept handy.
- First-aid box must be kept ready and timely replenishment of medicines must be ensured.
- **Safety of the students and teachers is more important than the safety of the apparatus.** Generally, in the beginning of the session, the teacher takes the students around the laboratory to familiarise them with the general facilities, equipment, apparatus, chemicals, glassware, etc. available in the laboratory and informs them about certain do's and don'ts while working in the laboratory.

3.3 Equipment of Science Laboratory

(i) General Science Laboratory (For Secondary schools)

- Working tables (ordinary) with drawers.
- Demonstration table (8' x 4') provided with gas and water points.
- A minimum of two sinks be provided in the corner of the laboratory.
- A white board or black board.
- Stools (in two sizes)
- Almirahs (wooden or steel) etc.
- Card board
- Colour papers
- Thermometers
- Mirrors
- Lenses
- Magnets (bar magnet, horse magnet etc.)
- Torch light
- Bulb
- Bottles
- Measuring cylinder
- Meter scale
- Ammeter
- Voltmeter
- Stand (wooden & iron)
- Spring balance
- Litmus papers (Red & blue)
- Salt
- Colur chalk
- Important chemicals
- Test tube
- Other low cost materials for performing activities and demonstration purposes.

(ii) Physics Laboratory (For Higher Secondary schools/ Teachers' Training Institutions)

- Working tables (ordinary) with teak wood top.
- At least one table having gas point fitted to it. This may be used for experiments on heat.
- Projected platforms for balances.
- Almirahs.
- Long working tables having drawers
- White board or black board.
- Two large sinks at the corners of the laboratory.
- Stools
- Dark room etc.

(a) Instruments and accessories

SL.	Instruments and accessories
1	Vernier callipers12.5 cm. long reading to
	0.1 cm. made of stainless steel , superior quality
2	Rods of Different diameter
3	Screw Gauge 0 - 25 mm in Box
4	Spherometer Double Disc - Brass
5	Physical Balance - Varanasi Make "National" Brand Capacity 250 gms. Sensitivity 1 Mg.
6	Hydrostatic Balance with 3rd pan - Varanasi make
7	Weight Box Physical : Complete with weight of 1 mg to 100 mg
8	Pendulum: Stand + Bob+ Clamp. 1 meter long.
9	Stop Watch "Digital"
10	Meter scale of seasoned Wood
11	Half meter scale of seasoned Wood
12	Drawing Board size 23" x 16" Pyne Wood
13	Mercury Thermometer Precision Type 0 - 360 C

14	Clinical Themometer - (superior Quality)
15	Plain Mirror Strip with Stand: size - 6" X 2" and highly polished
16	Glass Slab: Made of English Glass Slightly Greenish free from air bubbles,Size: 100x65x18mm
17	Glass Prism : Best Quality free from air bubles 60 angle 50 X 50 mm
18	Rheostat : Wounded on non-inductive, non-magnetic core with oxidized eureka wire 20 SWG 96 Ω
	Range 0 - 500 ohms
	Range 0 - 1000 ohms
19	Battery Eliminator: 220 volts AC output 0 - 12 volts

20	Post office Box: Best Quality manganin Coil with ratio 1:10:100 and 1000 ohms.
21	Spirit Level: 100 mm length in metallic case. Brass
22	Tuning Fork: set of 8 forks 5 cm length steel NP
23	Lamp House for Above
24	Stop Clock 60 sec: Accuracy +/- sec.
25	Magnetic Compass : 2 cm diameter both side glass
26	Screw driver set with detachable common handle (Set of 5 pcs) TAPARIA
27	Horse Shoe Magnet : 2" length
28	Convex lens : 5 cm dia. Optically true, free from achromatic aberration 15 cm focal length 20 cm focal length
29	Concave lens : 5 cm dia. Optically true, free from achromatic aberration 15 cm focal length

	20 cm focal length
30	Connecting wire D.C.C. 20 SWG
31	Ammeter with base & terminal : , 0 - 5.
32	Volt meter with base and terminal : 0 - 5.
33	Galvanometer with base & terminal : 30 - 0 - 30
34	Milliameter & Millivoltmeter : 0 - 500
35	Lens Holder on Stand - Spring Type.
36	Pin on Stand

(b) Experimental Set up

SL. No.	Experimental Set up
1	To find the weight of a given body using parallelogram law of vectors (Gravesend's apparatus)
2	To find the spring constant of a helical spring by method of oscillations using three different masses
3	To determine the surface tension of liquid by capillary rise method only capillary apparatus)
4	To determine the coefficient of viscosity of a given viscous liquid by measuring the terminal velocity of a given spherical body
5	To study the relationship between the temperature of a hot body and time by plotting a cooling carve
6	To find the speed of sound in air at room temperature using a resonant tube by two resonance positions (Resonant air column)
7	To find the relation between frequency and length of a given wire under constant tension using Sonometer

SL.	Experimental Set up
8	To find resistance of a given wire using meter bridge and hence determine the specific resistance of its material consisting of 1) Meter Bridge 2) Jockey 3) Resistance Box 4) Nichrome Wire 5) Screw Gauge & Meter Scale 6) Connecting Wire 7) Galvanometer
9	To determine resistance per cm of a given wire by plotting a graph of potential difference versus current consisting of 1) Wire (Nichrome) 2) Voltmeter 3) Ammeter 4) Meter Scale 5) DC Power Source
10	To verify the laws of combination (series / parallel) of resistance using a meter bridge consisting of 1) Meter Box 2) Resistance Box 3) Plug Commutator

	4) Single Resistance Box : 2 Ω Single Resistance Box : 5 Ω Single Resistance Box : 10 Ω 5) Galvanometer

SL. No.	Experimental Set up
11	To find the value of v for different value of u in a case of a concave mirror and to find the local length consisting of 1) Concave Mirror 2) Knitting Needle 3) Meter Scale
12	To determine the focal length of a convex mirror using a convex lens consisting of 1) Optical Bench with pin 2) Convex Lens 3) Convex Mirror
13	To find length of a convex lens by plotting graphs between u and v or between 1/u and 1/v consisting of 1) Optical Bench 2) Convex Lens

SL. No.	Experimental Set up

14	To fond the focal length of a concave lens using a convex lens consisting of 1) Optical Bench 2) Concave Lens 3) Convex Lens
15	To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and angle of deviation consisting of 1) Prism 2) Board Pin 3) Hair Pin
16	To determine refractive index of a glass slab using a travelling microscope consisting of 1) Glass Slab 2) Travelling Microscope
17	To find the refractive index of a liquid by using (i) concave mirror, (ii) convex lens and plane mirror consisting of 1) Concave Mirror 2) Meter Scale 3) Optical Pin 4) Stand with Clamp 5) Spherometer 6) Plumb Line 7) Convex Lens

	8) Meter Scale

SL. No.	Experimental Set up
18	To compare the emf of two given primary cells using potentiometer consisting of 1) Potentiometer with Jockey 2) Primary Cells 3) Millammeter 4) D.C. Power Source 5) Resistance Box 6) One Way & 2 Way Key 7) Galvanometer
19	To determine the internal resistance of given primary cell using potentiometer consisting of 1) Potentiometer 2) D.C. Power Source 3) Galvanometer 4) Resistance Box 5) Ammeter 6) Fractional Resistance Box 7) Primary Cell (Laclance Cell / Daniel Cell)

\20	To determine resistance of a galvanometer by half-deflection method its figure of merits consisting of 1) Weston Type Galvanometer 2) Battery 3) Resistance Box
21	To convert the given Galvanometer (of known resistance and figure of merit) into an ammeter and voltmeter of desired range and verify the same consisting of 1) Galvanometer 2) Rheostat 3) Constantan Wire / Manganin Wire 4) Screw Gauge 5) Wire Cutter 6) Battery Eliminator 7) Resistance Box 8) Milliameter 9) Voltmeter

SL. No.	Experimental Set up
22	To find the frequency of the A.C. mains with a sonometer consisting of

	1) Sonometer 2) Soft Iron Wire 3) Tunning Fork 4) Hanger 5) Slotted Weight 6) Step Down Transformer 7) Electromagnet 8) Stand with Clamp 9) Meter Scale

23	To draw the I - V characteristic curve of a p - n junction in forward bias and reverse bias consisting of 1) Bread Board 2) Jn diode : OA – 70 Jn diode : OA – 71 Jn diode : OA – 72 Jn diode : BY – 125 Jn diode : BY – 127 3) D.C. Voltage Source 4) Milliammeter 5) Voltmeter

	6) Microammeter 7) Rheostat

SL. No.	Experimental Set up
24	To draw the characteristic curve of a zener diode and to determine its reverse break down voltage consisting of 1) Zener Diode IN 758 A IN 962 B 2) D.C. Power Supply 3) Microammeter 4) Voltmeter 5) Rheostat 6) Bread Board 7) POT
25	To study the characteristic of a CE npn / pnp transistor and to find out the value of current gain & voltage gain consisting of 1) Bread Board 2) Transistor : SL – 100 Transistor : SL – 100 Transistor : CL – 100 Transistor : BC – 147 Transistor : BC – 148

	Transistor : AC – 187 Transistor : 2SB – 77 Transistor : 2N -2904 3) D.C. Power Supply 4) POT 5) Milliammeter 6) Microammeter 7) Voltmeter 8) Multimeter

(ii) Chemistry Laboratory (For Higher Secondary schools Teachers' Training Institutions)

- Almirahs (wooden or steel)
- White board or black board.
- Working tables with cupboards, shelves, water and gas points/island bench
- Sinks on each working table or least two large sinks at the corners of the laboratory.
- A fume cupboard.
- A wooden box half filled with sand for use as waste material box.
- Acid proof drainage system.
- Shelves for reagent bottle on each working table and wall shelves for storage of reagent bottles etc.

(a) Equipment

SL	Equipment
1	Test Tube Branded
2	Burrette
3	Pipette Volumetric
4	Conical Flask 50ml
5	Conical Flask 250ml

6	Conical Flask 500ml
7	Burrette Stand
8	Test Tube Stand
9	Watch Glass 100mm
10	Thermometre (Heating)
11	Thermometre (Cooling)
12	Measuring Flask 100ml
13	Measuring Flask 250ml
14	Measuring Cylinder 10ml
15	Measuring Cylinder 100ml
16	Measuring Cylinder 250ml
17	Digital Balance(Metal Aj-420 E)
18	Test Tube Holder
19	Glass Rod
20	Spatula
21	Funnel
22	Seperating Funnel 250ml
23	Round Bottom Flask 250ml
24	Condenser
25	Ignition Tube
26	Bunsen Burner
27	Platinum Wire
28	Spirit Lamp
29	Distilling Flask

30	Brush
31	Flat Bottomed Flask 250ml
32	Porcelain Basin
33	Mortar And Pestle
34	Liebig Condenser
35	Kipp's Apparatus 500ml
36	Water Bath
37	Volumetric Flask
38	Ph Meter(1 Set) And Papers (10)
39	Litmus Paper (Red & Blue)
40	Cupper Tube
41	Fusion Tube
42	Ice Bath
43	Petridish
44	Woulf's Bottle
45	Wire Gauge
46	Tripod Stand
47	Seperating Funnel Holder
48	Test Tube Basket 14 X 12 X 11
49	Filtering Flask 500ml
50	Filter Paper-9 Cm Dia
51	Parafilm (4in.X125ft)
52	Cork

53	Capillary Tube
54	Dropper
55	Stop Watch
56	Gas Jar
57	Jar Cover
58	Whatman Filter Paper 70mm(Aldrich)
59	Fire Capillary Tube
60	Hand Gloves
61	Flat Bottomed Flask 500ml
62	Distilled Water
63	Oven-300 ^{O}c With Vacum Facility
64	Refrigerator
65	Magnetic Stirrer With Heating
66	Beaker 100ml
67	Beaker 250ml
68	Beaker 500ml

(b) Chemicals

SL.	Chemicals
1	Ammonium Sulphate
2	Mohr's Salt
3	Acetone

4	Aluminium Chloride
5	Boric Acid
6	Borax Powder
7	Beta Napthol
8	Glacial Acetic Acid
9	Copper Sulphate
10	Calcium Sulpahte
11	Calcium Carbonate
12	Calcium Nitrate
13	Disilled Water
14	Ethanol
15	Methanol
16	Sulphuric Acid
17	Hydrochloric Acid
18	Nitric Acid
19	Ferrous Sulphate
20	Glycerol
21	Fehling-A
22	Fehling-B
23	Magnesium Sulphate
24	Magnesium Chloride
25	Manganese Dioxide
26	Potasium Dichromate
27	Potasium Permanganate

28	Potasium Chloride
29	Oxalic Acid
30	Sodium Bicarbonate

31	Sodium Nitrate
32	Sodium Hydroxide Beads
33	Zinc Sulphate
34	Zinc Chloride
35	Zinc Dust
36	Potasium Carbonate
37	Barium Chloride
38	2,4 Dnp
39	Sodium Bismuthate
40	Starch
41	Alum
42	Phenolpthalein
43	Sodium Chloride
44	Methyl Orange
45	Vaniline
46	Acetanilide
47	Benzaldehyde
48	Calcium Hydroxide- Gr Grade
49	Lead Acetate Solution

50	Phenol
51	Sodium Sulphate
52	Sodium Thiosulphate
52	Sodium Nitroprusside
53	Ferrous Chloride
54	Ferrous Sulphide

Short Questions with Answers

Marks - 2

Q. State any two objectives of Laboratory work.

Ans: Laboratory work facilitates in the development of (i) cognitive abilities, i.e. principles and laws discussed in the classroom may precede or follow the laboratory work or it may be carried out during discussion; (ii) process skills of Science;

Q. Mention the importance of Science laboratory.

Ans: The importance of Science laboratory is as follows:

- In a laboratory the student performs the experiment and on the basis of the experiment he attains practical knowledge from theoretical knowledge.
- The student learns from his experiences. He develops the power of thinking, observation and decision-making.
- The students develop self-discipline and self-confidence.
- The students understand the topic clearly and easily.

Q. Highlight some laboratory techniques in Physical Science.

Ans: Following are the laboratory techniques in Physical Science:
(i) Cutting a glass tube.
(ii) Drilling holes in glassware
(iii) Preserving chemicals
(iv) Preserving instruments and materials from dust, water and heat.

Q. Name four common laboratory accidents.

Ans: Following are the **four common laboratory accident:**
(i) Fire (ii) Burns (iii) poisoning and (iv) Cuts / injuries

Q. Highlight the administration of the laboratory.

Ans: **Administration of the laboratory is as follows:**
(i) Organizing and conducting practical works
(ii) Grouping of pupils
(iii) Preparation for individual and group working
(iv)Discipline
(v)Instruction to pupils

Q. Mention the procedure adopted by a Physical Science teacher while purchasing the apparatus and materials.

Ans: Following procedure should be adopted by a Physical Science teacher while purchasing the apparatus and materials:
(i) Selection of apparatus and chemicals
(ii) Purchase

(iii) Arrangement
(iv)Care and maintenance

Q. Name different Stock Registers used in Physical Science Laboratory.
Ans: The Articles should be entered and maintained in the following Stock Register:
(i) Permanent Stock Registers – Article of metal, wood or of permanent nature such as iron stand, metallic bob, magnet, and meter scale, electrical and non-electrical instruments
(ii) Breakable Stock Registers – Article of glass-water such as flask, beaker, thermometer etc.
(iii) Consumable Stock Registers

Probable Questions

Very short answer type questions **Marks - 2**

1. State any two objectives of Laboratory work
2. Mention the importance of Science laboratory.
3. Highlight some laboratory techniques in Physical Science.
4. Name four common laboratory accidents.
5. Highlight the administration of the laboratory.
6. Mention four important skills of a Physical Science teacher required for Laboratory Work
7. Mention the procedure adopted by a Physical Science teacher while purchasing the apparatus and materials.
8. Name different Stock Registers used in Physical Science Laboratory.

Short answer type questions **Marks - 5**

1. Discuss the importance of practical work in Science teaching? What are the main points to be kept in mind while organizing practical work?
2. Draw a plan of Physics and Chemistry Laboratory Higher Secondary level.
3. What precautions should the teacher take in the laboratory administration?
4. How can the good laboratory administrations help in the achievements of objectives of teaching of Physical Science?
5. Discuss briefly how you will plan to conduct a practical class.

Long answer type questions **Marks - 10**

1. How would you organize a Science Laboratory in a Secondary school?
2. Make a list of equipment required for Science Laboratory of Secondary school.
3. How far can the development of laboratory skills in the children help for effective Science learning?
4. Make a list of the laboratory techniques in Physics and Chemistry which every child at the High school must learn. Give details of two techniques from the list.