CHAPTER II

CONCEPTUAL REVIEW
The chapter deals with a conceptual review of science education and related areas envisaged in the study. The review is done under the following titles, for convenience.

- Science Education
- Science Process Skills
- The science learner
- The science teacher

(A) SCIENCE EDUCATION

"Sixty years ago I knew everything; now I know nothing; education is a progressive discovery of our own ignorance" - Will Durant

Education is visualized as the greatest hope for creating a more sustainable future and it holds the promise to gear up social and economic development on a sustainable basis. It is education that acts as a decisive factor in enabling people to become productive and responsible members of the society. Since education has a leading role in catalyzing development, investing in education is now globally regarded as one of the centerpieces of development. Quality education reflects the desire of the learner to learn. Science education is expected to provide the opportunity to acquire the essential knowledge, skills and attitudes required to function in the modern world. Science education emphasizes the acquisition of skills and competencies for the productive application of acquired knowledge resulting in human welfare. The overwhelming contribution of scientifically and
technologically enlightened population towards the development of society would be surprising. Hence, a good science education is important for every child, and not just for those who may be headed towards a scientific or technical career.

Science is everywhere, and understanding how it’s a part of our daily lives can help give kids a great foundation for success in life. As the American Association for the Advancement of Science (AAAS) announced in ‘Science for All Americans’ (Rutherford & Ahlgren, 1990) *What the future holds in store for individual human beings, the nation, and the world depends largely on the wisdom with which humans use science and technology. And that, in turn, depends on the character, distribution, and effectiveness of the education that people receive.* Accordingly, **scientific literacy** has become a major goal of science education. Although there is no consensus regarding what kinds of science content are necessary for scientific literacy, a scientifically literate person is believed to be one who appreciates the strengths and limitations of science and knows how to use scientific knowledge and scientific ways of thinking for living a better life and for making rational social decisions (Sandra, Yager, 1998).

Children are naturally curious. Science education feeds that curiosity and provides students with valuable concepts, life skills, and career options. Science can help them succeed by providing truly useful life skills....

- **Science helps children understand and appreciate the world.** When children explore and learn about the world around them and how it works, they gain a better understanding of, and appreciation for, nature and the interdependence of living things and their environments.

- **Science promotes strong communication skills.** Whether by working on independent science projects that require written or oral reports, or through group experiments that involve discussion and debate, cooperation and consensus, students must employ effective communication skills when reporting on their research. In the long run, these communication abilities can foster creativity and translate into effective personal relations and
business presentation skills, because students learn about dealing with conflicting viewpoints, and understand that there are occasions when they need to collaborate and other occasions when they need to work independently.

- **Science teaches strong research skills.** Through science, students learn about coming up with hypotheses, collecting data, testing hypotheses, reading about prior research, looking for patterns, communicating their findings, report writing, making presentations and conducting further testing. These skills are crucial for later success in higher studies and in the world of work.

- **Science provides a healthy dose of skepticism.** When children think as scientists do, by questioning things and considering new approaches, they gain independent thinking skills that can help them develop into savvy and wise consumers, voters, and citizens who can make their own informed decisions.

**CURRICULAR INNOVATIONS IN SCIENCE**

Since 1960, the teaching of science became a major concern that it received global attention. This was a period of intense and vigorous development in the science curriculum, marked by the publication of many major projects. The major curricular innovations launched as a revolt against the traditional product-led approach stress the development of processes in science teaching. Physical Science Study Committee (PSSC), Science - A Process Approach (SAPA), Harvard Project Physics (HPP), The Elementary Science Study (ESS), The Science Curriculum Improvement Study (SCIS), The Elementary School Science Project(ESSP), School Science Curriculum Project(SSCP), The Minnesota Mathematics and Science Teaching Project (MINNEMAST), Conceptually Oriented Program in Elementary Science (COPES), Chemical Education Material Study (CHEM study), Chemical Bond Approach (CBA), Science in Process, Warwick Process Science, various Nuffield courses in the U.K. and ASEP in Australia are some of them. A recurring and
significant feature of most of these curriculum proposals was a major shift in emphasis away from the teaching of science as a body of established knowledge, toward science as a human activity with increasing emphasis on the processes and procedures of science. The curriculum projects are framed in such a way that children should enjoy science through direct engagement in scientific activities and gain an awareness of what scientists do. They should also be encouraged to pursue the study of science at an advanced level.

**SCIENCE CURRICULUM IN INDIA**

The Education Commission chaired by Prof. D.S. Kothari has been an important landmark for its depth and expanse of vision of education in India. The science curriculum in India has undergone several changes, both in approach and content, during the last forty years or so. Major curricular renewal programmes in science in India have evolved in keeping with contemporary global trends in science education and the changing societal needs.

**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 (National Curricular Framework, N.C.F -2005):

a) **Cognitive validity** 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** 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 trivialized as to convey something basically flawed and/or meaningless.

c) **Process validity** 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** 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** 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** 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.

Consistent with the criteria above, the objectives, content, pedagogy and assessment at the secondary stage highlight that 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. Participation in co-curricular activities must be regarded as equally important at this stage. These may involve taking up projects (in consultation with teachers) that bear on local issues and involve the problem-solving approach using science and technology. The various components of the science curriculum should be integrated imaginatively. The entire upper primary and secondary school curriculum should have horizontal integration and vertical continuity. Science learning should be used as an instrument of social change to reduce the socio-economic divide. It should help to fight prejudice related to, among others, gender, caste, religion and region. Science education ought to
empower students to question the social beliefs, notions and practices that perpetuate social inequality.

**The general aims of science education**

The general aims of science education (NCF, 2005) follow directly from the above six criteria of validity. Thus, science education should enable the learner to:

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

Research in science education, experiences of curricula at national and state levels over the past several decades and different interventional programmes of voluntary groups have shed considerable light on the scope and gradation of the school curriculum. While deciding on gradation of science curriculum, it must be borne in mind that a majority of students learning science as a compulsory subject up to Class X are not going to train as professional scientists or technologists in
their later careers; yet they need to become ‘scientifically literate’, since several of
the social, political and ethical issues posed by contemporary society increasingly
revolve around science and technology. Consequently, the science curriculum up
to Class X should be oriented more towards developing awareness among the
learners about the interface of science, technology and society, sensitizing them,
especially to the issues of environment and health, and enabling them to acquire
practical knowledge and skills to enter the world of work. It should stress not only
the content of science, but, more importantly, the process skills of science, that is,
the methods and techniques of learning science. This is necessary since the process
skills are more enduring and enable the learner to cope with the ever changing and
expanding field of science and technology (N.C.F, 2005).

Kerala, the most literate and educationally elite state in the southern
region, is way ahead of all other Indian states in popularising general education.
The curriculum revision programme in Kerala was conceptualized on the basis of
the recommendations of the National Curriculum Framework (N.C.F-2005). The
curriculum is revised on the premise that education is a social process. The
following strategies were adopted for the framing of the curriculum (Dept. of
Education, Govt. of Kerala, 2009).

- Activity based and process oriented learning strategies
- Investigative learning activities
- Learning experiences that aim at comprehensive development
- Free, democratic and child friendly atmosphere in the class
- Effective utilization of learning materials including textbooks
- Continuous and comprehensive evaluation
- Creative assistance and interventions of the society

Currently, Kerala displays the active working model of a learning process
that has its foundation in the principles of constructivism and a learner-centred,
activity-based and process-oriented pedagogy. Rooted in the emerging
methodology and strategies, an integrated method of learning, a process-oriented-activity-based approach that views the learner as a constructor of knowledge and that recognizes the role of society in knowledge construction and the idea of continuous and comprehensive evaluation came into effect. However, the state’s curriculum reform effort gained further impetus with the formulation of the National Curriculum Framework (NCF) -2005. NCF-2005 and the position papers provided grounds for introspection and formulation of the Kerala Curriculum Framework (KCF)-2007.

SCIENCE EDUCATION: THE APPROACH

The approach of science education has to be changed to achieve the aims stated above. The conventional notion of science education as that transferring accumulated knowledge about the universe has been changed almost four decades ago. After this, the idea that process of learning science is as important as the content (product) of science came to the fore. But now prominence is given to the view that there are other areas to be considered apart from process and the content (KCF,2007). This outlook has received wide support from educationalists and scientists. According to “The Taxonomy of Science Education” (McCormack, Yager 1989), science education should give emphasis to the following five important domains.

a) Knowledge Domain

Every student of science ought to be aware of the latest theories and developments in the field of science. Natural phenomena, the relation between these phenomena, explanation about these phenomena etc. are comprehended through science learning. The knowledge domain includes

- facts,
- ideas,
- laws,
- hypotheses and theories that the scientists use
- correlation of science and social issues.
These could be accomplished by observation and experiment, discussion, debate, project work and reference etc.

**b) Science Process Domain**

This area helps to understand how scientists construct knowledge and how the learner can do it by himself/herself. It gives emphasis to “learn to learn”. A process could be defined as a series of steps that aim at a particular result. The ability to identify new ideas and analyze them to reach a conclusion is termed as process skills. Process skills are developed by collecting ideas and proof and by arriving at conclusions after deeper analysis. Concept formation is an essential part of any kind of study. But, in order to internalize an idea, the learner has to go through a series of learning process. The idea that the learner forms through observation and experimentation is his/her own. The knowledge thus acquired can be developed and put into practice in daily life. This really justifies the importance of process in learning. There are certain process skills that the learner ought to possess in order to engage in scientific study. They are:

- observation
- data collection and documentation
- classification
- measurement and charting
- data analysis
- engaging in experiments
- identifying variables
- questioning
- generalisation
- problem solving
- arriving at a hypothesis
- decision-making
- communication
- predicting and inferring
- handling tools
c) Creativity Domain

Science education is now viewed upon as the process that helps the learner gather information about some aspects of science. This perspective overlooks the creative thinking of the learner. The learner should be given chances to explore new paths in the acquisition of scientific knowledge. The learner should:

- Develop the potential for visualization
- develop the skill to design an experiment
- correlate ideas and facts in a new manner
- find an alternative utility for materials
- find answers for problems and puzzles
- start fantasizing
- design tools and equipment
- start dreaming
- think differently

d) Attitudinal Domain

The essential aim of science education is to create a desirable change in attitude and develop new ideas regarding values. Even after acquiring new ideas and process skills, if there is no change in the learner's attitude towards the society, science education will have no practical meaning. Science education should try to bring in a change in aspects like attitude, values and decision-making. Therefore, science education has to take into consideration these aspects as well:

- the learner ought to develop an inclination towards scientific knowledge and science education
- he/she should develop faith in one’s ability
- he/she ought to understand and value human emotions
- he/she ought to be sympathetic to others and their attitude

This can be achieved only by the interaction with society, students and teachers.

e) Application Domain

If the learner is not able to apply the knowledge that he/she has gathered, there is no meaning in imparting science education. If the practical level of science
education could not be related to life, the learner will not find it to be of any significance.

The elements of Application Domain are:

- observing science concepts in daily life
- making use of the concepts and skills that are imbibed for solving issues related to technology
- forming ideas about the scientific principles behind the working of tools and equipments used at home
- making use of the process of science to solve the issues in daily life
- developing ability to evaluate the events related to science
- taking scientific decisions in matters of food, health and life style
- developing an inter-disciplinary approach

Learning Methodology

A change in the attitude towards the skills that are to be inculcated in science education necessitates a change in the learning methodology as well. Science learning is something that students do, not something that is done to them. Science education should be an active learning process. A good learning activity has to:

- help in forming concepts and developing skills
- ensure participation of all
- motivate the cognitive development of the child
- be planned in advance so that the learner must feel it enjoyable and challenging
- be suitable to the age and nature of the learner

Secondary education in Kerala is universal and it covers learners of all sections of the society. This phase ought to create awareness in the learners regarding all fields of knowledge and to acquaint themselves with the resources available in each. Also, the activities must lead the children to recognize their abilities and identify the vocation that they should get engaged in future.
The pivot of science education should be the development of the spirit of scientific enquiry. With the help of science education, all learners should acquire the science process skills and inculcate the spirit of inquiry to understand the research methodology of scientists and construct new forms of knowledge.

(B) SCIENCE PROCESS SKILLS

“Tell me and I forget. Show me and I remember. Involve me and I understand” - Chinese proverb

Science is one of the great expressions of humanity. James. B. Conant, an eminent scientist and educator, has defined science as “an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation, and are fruitful to further experimentation and observation”. Science is simultaneously a body of knowledge and a way of gaining and using that knowledge. The accumulated and systematized body of knowledge, which is the ‘product’ of science, has a dynamic counterpart, the methods of inquiry, which is the ‘process’ of science. Science is thus a combination of both ‘processes’ and ‘products’ related to and dependent upon each other.

The spirit of science should be imbibed in everyone, not in a few. The children of today have to identify scientific principles and applications around them in their daily life. In this world of knowledge explosion, it is very difficult for education planners and teachers to keep in pace with the expanding knowledge. So, right from the elementary school, children should be taught ‘how to know’ of science, rather than ‘what to know’. The NSTA (1971) has rightly commented: “To cope with the attempt to solve problems in a rapidly changing society, young people will need to develop science process skills and associated values to a greater extent than in the past”.

A process approach to science is one in which children do something with the concepts and generalizations they learn. It implies that students can manipulate, decide, solve, predict, and structure the knowledge of science in ways...
that are meaningful to them. When teachers and parents provide opportunities for students to actively process information, particularly information related to nature, then learning becomes more child-centered. This results in attitudes, perceptions, and beliefs that the natural world can be actively explored and personally investigated and that the environment, both near and far, is full of incredible learning possibilities along with a whole lot of fun.

In general, process skills refer to the cognitive processes or thinking processes in which the learner is engaged while learning a subject. The exercise of these process skills generates the ‘products’ of learning a particular subject - meaning, definition, explanation of terms, concepts, principles, laws, theories, etc., in the domain of that subject. Thus, the products of learning a subject are generated through the use of the process skills by the learner. Those process skills which are more often used and emphasized by learners of science and scientists and which are productive in better learning and problem solving - such as observing, classifying, measuring, inferring, predicting, hypothesizing, experimenting, etc., may be called process skills in science.

The meaning of the “process of science” is expressed in many ways. The American Association for the Advancement of science – AAAS, (Mayar, 1962-68) in their programme, Science- A Process Approach (SAPA) perceives it as a corresponding de-emphasis on specific science “content”, and more emphasis on science processes. SAPA holds that science is what scientists do. As defined by SAPA, the science process skills are a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists.

According to Gagne (1965), process skills involve ways of processing information and such processing grows more complex as an individual develops from early childhood onwards. The meaning of ‘process’ centers upon the idea that, what is taught to children should resemble what scientists do – the processes that they carry out in their own scientific activities.
Science process skills (SPS) facilitate learning in basic sciences, ensure active student participation, have students develop the sense of undertaking responsibility in their own learning, increase the permanence of learning, and also have students acquire research ways and methods. For this reason, SPS are the building blocks of critical thinking and inquiry in science (Ostlund, 1992).

CLASSIFICATIONS OF SCIENCE PROCESSES

A Process is a series of activities or operations performed to attain certain goals or products. Science Processes are the inter-linked activities performed by any qualified person during the exploration of the universe. The Science process skills are the intellectual skills needed for scientific investigation attained by students as a result of learning of science. Different educators and psychologists have given different classifications of science processes. Some of the representative classifications are given below:

(a) NAY’s CLASSIFICATION OF SCIENCE PROCESSES

Nay et.al. (1971) identified five steps of scientific inquiry, with seventeen subdivisions and many other minor divisions. Their scheme of scientific inquiry is as follows:

A. Initiation

1. Identifying and formulating a problem
   a. speculating about a phenomenon
   b. identifying variables
   c. noting and making assumptions
   d. delimiting the problem.

2. Seeking relevant background information
   a. recalling relevant knowledge and experiences
   b. doing literature research
   c. consulting
3. Predicting

4. Hypothesizing

5. Design for collection of data through field work and / or experimentation
   a. defining the independent and controlled variables in operational terms
   b. defining the procedure and sequencing the steps
   c. identifying needed equipment, materials and techniques
   d. indicating safety precautions
   e. devising the method for recording data

B. Collection of data

6. Procedure
   a. collecting, constructing and setting up the apparatus or equipment
   b. doing field work and / or performing the experiment
   c. identifying the limitation of design (as a result of failures, blind alleys etc.,) and modifying the procedure (often by trial and error)
   d. repeating the experiment (for reproducibility, to overcome the limitations of initiation, design, etc.)
   e. recording data (describing, tabulating, diagramming, photographing etc.)

7. Observations
   a. obtaining qualitative data (using senses, etc.)
   b. obtaining semi-quantitative and qualitative data (measuring, reading scales, calibrating, counting objects or events, estimating, approximating, etc.)
   c. gathering specimens
   d. obtaining graphical data (charts, photographs, films, etc.)
   e. noting unexpected or accidental occurrences (serendipity)
   f. noting the precision and accuracy of data
   g. judging the reliability and validity of data
C. Processing of data

8. Organizing the data
   a. ordering to identify regularities
   b. classifying
   c. comparing

9. Representing the data graphically
   a. drawing graphs, charts, maps, diagrams, etc.
   b. interpolating, extrapolating, etc.

10. Treating data mathematically
    a. computing (calculating)
    b. using statistics
    c. determining the uncertainty of the results

D. Conceptualization of data

11. Suggesting an explanation
    a. for a set of data
    b. deriving an influence or generalization from a set of data
    c. assessing validity of initial assumptions, predictions and hypotheses

12. Formulating operational definitions
    a. verbal
    b. mathematical

13. Expressing data in the form of mathematical relationship

14. Incorporating the new discovery into the existing theory. (developing a 'Mental Model')

E. Open endedness

15. Seeking further evidence to
    a. increase the level of confidence in the explanation or generalization
    b. test the range of applicability of the explanation or generalization
16. Identifying new problems for investigation because of
   a. the need to study the effect of new variable
   b. anomalous or unexpected observations
   c. incompleteness (gaps) and inconsistencies in the theory

17. Applying the discovered knowledge

(b) UNESCO's CLASSIFICATION OF SCIENCE PROCESSES

UNESCO source book for science teaching (1992) lists out the various science process skills and their indications. They are:

**Observing**
- Using the senses (as many as safe and appropriate) to gather information
- Identifying differences between similar objects or events
- Identifying similarities between different objects or events
- Noticing fine details that are relevant to an investigation
- Recognizing the order in which sequenced events take place
- Distinguishing from any observations those which are relevant to the problem in hand

**Raising questions**
- Asking questions which lead to inquiry
- Asking questions based on hypotheses
- Identifying questions which they can answer by their own investigation
- Putting questions into a form, which indicates the investigation which has to be carried out
- Recognizing that some questions cannot be answered by inquiry
Hypothesizing

- Attempting to explain observations or relationships in terms of some principle or concept
- Applying concepts or knowledge gained in one situation to help understand or solve a problem in another
- Recognizing that there can be more than one possible explanation of an event
- Recognizing the need to test explanations by gathering more evidence
- Suggesting explanations, which are testable, even if unlikely

Predicting

- Making use of evidence to make a prediction (as opposed to a guess, which takes no account of evidence)
- Explicitly using patterns or relationships to make a prediction
- Justifying how a prediction was made in terms of present evidence or past experience.
- Showing caution in making assumptions about the general application of a pattern beyond available evidence
- Making use of patterns to extrapolate to cases where no information has been gathered.

Finding patterns and relationships

- Putting various pieces of information together (from direct observations or secondary sources) and inferring something from them
- Finding regularities or trends in information, measurements or observations
- Identifying an association between one variable and another
• Realizing the difference between a conclusion that fits all the evidence and an inference that goes beyond it

• Checking an inferred association or relationship against evidence

Communicating effectively

• Using writing or speech as a medium for sorting out ideas or linking one idea with another

• Listening to others' ideas and responding to them

• Keeping notes on actions or observations

• Displaying results appropriately using graphs, tables, charts, etc

• Reporting events systematically and clearly

• Using sources of information

• Considering how to present information so that it is understandable by others

Designing and making

• Choosing appropriate materials for constructing things, which have to work or serve a purpose

• Choosing appropriate materials for constructing models

• Producing a plan or design which is a realistic attempt at solving a problem

• Making models that work or meet certain criteria

• Reviewing a plan or a construction in relation to the problem to be solved

Devising and planning investigations

• Deciding what equipment, materials, etc. are needed for an investigation

• Identifying what is to change or be changed when different observations or measurements are made

• Identifying what variables are to be kept the same for a fair test
• Identifying what is to be measured or compared
• Considering beforehand how the measurements, comparisons, etc. are to be used to solve the problem
• Deciding the order in which steps should be taken in an investigation

**Manipulating materials and equipment effectively**

• Handling and manipulating materials with care for safety and efficiency
• Using tools effectively and safely
• Showing appropriate respect and care for living things
• Assembling parts successfully to a plan
• Working with the degree of precision appropriate to the task in hand

**Measuring and calculating**

• Using an appropriate standard or non-standard measure in making comparisons or taking readings
• Taking an adequate set of measurements for the task in hand
• Using measuring instruments correctly and with reasonable precision
• Computing results in an effective way
• Showing concern for accuracy in checking measurements or calculations

(c) **GAGNE’S HIERARCHY OF LEARNING TYPES**

Gagne formulated a model based on the hierarchy of learning types. In this model, learning of more basic behaviour is a pre-requisite for learning of the higher behaviour. This idea has been systematised by Gagne (1977) in the form of a hierarchy of learning types.

1. Signal learning
2. Stimulus response learning
3. Chaining
4. Verbal association
5. Discrimination learning
6. Concept learning
7. Rule learning
8. Problem solving

Gagne later (1985) modified this hierarchy of eight learning types. He retained the first four in the same order, and modified the latter four higher types into five varieties of capabilities, as he called them. These capabilities are:

1. **Intellectual skills**: Intellectual skills are the most important types of capabilities learned by human beings. They include, successful handling of symbols for communication with environment. The most typical form of an intellectual skill is a rule. Intellectual skills consist of the following categories:
   - multiple discrimination
   - concrete concept and defined concept
   - higher order principles or learning of rules
   - procedure

2. **Cognitive strategies**: Cognitive strategies are internally organized skills whose functioning is to regulate and monitor the utilization of concepts and rules. By acquiring and using cognitive strategies the learners are able to regulate internal processes such as,
   - attending
   - learning
   - remembering
   - thinking
   - problem solving
3. **Verbal information**: The learner has to learn verbal information and retain it, so that, it is immediately accessible. Information is thought of as verbal and capable of being verbalised.

4. **Motor skills**: Acquisition of motor skills is the organisation of movements to constitute a total action that is smooth, regular and precisely timed.

5. **Attitudes**

   Gagne’s hierarchy implies the structure of scientific process. It serves as the background psychological principle for the preparation of the innovative curricula, SAPA, which emphasizes science processes (AAAS).

### (d) CLASSIFICATION OF SCIENCE PROCESS SKILLS ACCORDING TO AAAS

As defined by Science- A Process Approach (SAPA), the science process skills are a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists. SAPA has classified the thirteen science process skills into two types - basic and integrated. The eight basic (simpler) process skills provide a foundation for learning the five integrated (more complex) skills. These skills are listed below.

**Basic Science Process Skills**

1. **Observing**
   - Using five senses to obtain information

2. **Using time-space relationship**
   - Describing spatial relationships and their change with time

3. **Classifying**
   - Imposing order on collections of objects or events

4. **Using numbers**
   - Identifying quantitative relationships in nature

5. **Measuring**
   - Measuring length, area, volume, weight, temperature, force and speed

6. **Inferring**
   - An explanation of an observation.
7. **Communicating**  
Expressing ideas with oral and written words, diagrams, maps, graphs, mathematical equations, and various kinds of visual demonstrations.

8. **Predicting**  
Making specific forecasts of what a future observation will be.

**Integrated Science Process Skills**

1. **Controlling variables**  
Studying the influence of changing variables, the factors, which influence one another

2. **Interpreting data**  
Using data to make inferences, predictions and hypotheses, the statistical treatments given to such interpretations, and the study of probability.

3. **Formulating hypotheses**  
Making generalized statements of explanations

4. **Defining operationally**  
Defining terms in the context of experience

5. **Experimenting**  
Larger process of using basic and integrated processes

A general discussion of the science processes as given by various experts reveals that, the science process skills have a hierarchical order. Some basic skills are needed for the acquisition of higher order skills. One can infer an overlap of many skills in a specific phase of a problem solving task. There are some commonalities among the various classifications of skills, but some of them lack the high degree of wholeness of the processes.

The science process skills include intellectual skills, associated psychomotor and affective skills that are concerned with the learning of science in all its aspects. A review of literature enlists the skills pertaining to the various domains. The skills in the cognitive domain include comparing, communicating, inferring, predicting, using number relations, using time/space relations/making operational definitions,
framing hypotheses, controlling variables, interpreting data, generalizing, raising questions, applying, quantifying, evaluating, designing investigations, finding relationships and patterns. Skills of observing, classifying, manipulating, experimenting and measuring pertain to the psychomotor domain while those in the affective level include wondering ’why’, enjoying the aesthetics of discovery, ‘aha’ experience, suspending judgement, persevering amidst difficulty and ambiguity and the readiness to give up pet hypotheses in the face for strong evidence to the contrary.

For the teaching and learning of science to be of substantial value, the students must be able to apply scientific concepts, procedures and attitudes to their wider life. The value of learning science is greatly enhanced when the students are lead into an extensive understanding and a practical conception of how scientific concepts and principles apply to themselves personally, to their families, their communities and their nation. A restricted and narrow understanding of science without expertise in the associated scientific skills is an understanding with very limited value. There are many process skills encompassed in the conduct of scientific inquiry. It is a complicated business, and it is not appropriate to teach all process skills at once or to teach all of them to students at all age levels. The concept of the spiral curriculum provides an appropriate guide for the teaching and studying of process skills in science. Appropriate selections of science process skills can be taught and studied in the early years of primary school. The young students can be given the opportunity to observe, handle things and explore the environment. The basic learning which pupils achieve from these initial experiences can be used as a basis for building a more extensive understanding of science process skills in the later years of primary school and in the secondary school.
SCIENCE PROCESS SKILLS: A BIRD’S EYE VIEW

The prime purpose of science education is to enable individuals to use scientific process skills; in other words, to be able to define the problems around them, to observe, to analyze, to hypothesize, to experiment, to conclude, to generalize, and to apply the information they have with the necessary skills. Science process skills (SPS) are a reflection of the methods used by scientists while generating information on science. These important skills include the processes, which can be applied in almost every stage of life, and which should be possessed and used by any individual in scientific literate societies to increase the quality and standard of life. Therefore, these skills affect the personal, social, and global lives of individuals. The SPS are a necessary tool to produce and use scientific information, to perform scientific research, and to solve problems. These skills can be gained by students through certain science education activities. (Harlen, 1999; Huppert, Lomask & Lazaroricit, 2002).

Science process skills are activities that scientists execute when they study or investigate a problem, an issue or a question. These skills are used to generate content and to form concepts (Sund & Trowbridge, 1973; Funk, Fiel, Okey, Jaus & Sprague, 1979; Carin & Sund, 1985; Collette & Chiappetta, 1986; Wellington, 1994). Science process skills can be classified as either basic science process skills or integrated science process skills (Carin & Sund, 1985; Collette & Chiappetta, 1986; Wellington, 1994). Integrated science process skills are regarded as more advanced than basic process skills (Collette & Chiappetta, 1986). Brotherton and Preece (1995) argue that scientists are able to use integrated skills effectively once they have mastered the basic skills.

From a range of process skills associated with scientific inquiry, some of the skills can be rated as being the very basic ones. Students should be introduced to these skills early in their school experience because so much of their success in subsequent guided studies requires a sound understanding and appropriate use of these skills. Basic science process skills apply specifically to foundational cognitive functioning in especially the elementary grades. In addition, these skills also form
the backbone of the more advanced problem-solving skills and capacities. They represent the foundation of scientific reasoning learners are required to master before acquiring and mastering the advanced integrated science process skills (Brotherton & Preece, 1995). Funk et al. (1979) maintain that basic science process skills are interdependent, implying that investigators may display and apply more than one of these skills in any single activity.

Integrated science process skills are immediate skills that are used in problem-solving. Integrated skills include skills such as identifying variables, constructing tables of data and graphs, describing relationships between variables, acquiring and processing data, analysing investigations, constructing hypotheses, operationally defining variables, designing investigations and experimenting (Funk et al., 1979). As the term integrated implies, learners are called upon to combine basic process skills for greater expertise and flexibility to design the tools they apply when they study or investigate phenomena. This process can lead to the realization and achievement of integrated science process skills as observable and demonstrable outcomes.

Science Process Skills are a means for learning and are essential to the conduct of science. Perhaps the best way to teach process skills is to let students carry out scientific investigations and then to point out the process skills they used in the course of the investigations. The following is a list of the basic and integrated science processes advocated by the American Association for the Advancement of Science (AAAS). These are best thought of as a set of intellectual skills that are associated with acquiring reliable information about nature. Each process is defined and described using relevant example(s) and their competency indicators. Each indicator is one of the many behavioral examples which may be used to assess student competency in the particular process skill.
Basic Science Process Skills

1. Observing

Observation is the most fundamental of all of the processes skills. An observation is simply a record of a sensory experience. Observation may be defined as the gathering of information about an object or event through the use of any one, or combination of the five basic senses; sight, hearing, touch, taste, and smell. Example: Describing a pen as red. The term observation may also be used to express the result of observing. In other words one might observe and, as a result, gather observations. These observations can also be called data or facts. Scientists use observation skills in collecting data. Observation is thus an objective process of gathering data through the use of one's senses applied in an analytical way.

Competency indicators:

- use one or more of the senses to gather information about an object/event.
- sense similarities and differences between objects
- match objects to a given description
- identify properties of an object, i.e., shape, color, size, and texture.

2. Classifying

Classification is the process of grouping objects on the basis of observable traits. Objects that share a given characteristic can be said to belong to the same set. Classifying involves grouping items into like categories. Items can be classified at many different levels, from the very general to the very specific. In most instances one should seek to classify on the basis of traits that are essential to the idea of the set. Example: Placing all rocks having certain grain size or hardness into one group. Science assumes that to a large degree the universe is consistent with its laws holding true everywhere. Therefore, if a set of objects share one thing in common they may well share other attributes. The nature of the skill of
classification is two fold. First, one must be able to identify traits and, second, one must select traits that express the deeper essence of the system.

**Competency indicators:**

- identify properties useful for classifying objects
- group objects by their properties/similarities and differences/criteria/observable traits
- construct and use classification systems in tabular and other visual forms.

3. Measuring

Measuring is an observation made more specific by comparing some attribute of a system to a standard of reference. Measuring uses both standard and non-standard measures or estimates to describe the dimensions of an object or event. Measurement and observation are the only process skills that are actually two forms of the same thing. Measuring is the process of making observations that can be stated in numerical terms. Example: Using a metre stick to measure the length of a table in centimetres. This is the process by which learners measure angles, numbers, sizes, lengths or distances, volumes and mass. The acquisition and practising of skills needed to do these measurements are essential for learners to be able to think in metric terms. All scientific measurements should be given in SI units.

**Competency indicators:**

- measure in a given situation using appropriate units to a suitable degree of accuracy
- use both standard and non-standard measures or estimates to describe the dimensions of an object.
- use both standard and non-standard measures or estimates in making comparisons or taking readings.
4. Using time/space relations

The process skill of relationships deals with the interaction of variables. This interaction can be thought of as a kind of influence--counter influence occurring among a system's variables. The inherent nature of this skill is that it requires analytical thought in which one seeks to dissect cause from effect. The causal elements are the system's variables and the effect is the resulting interaction. This describes spatial relationships and their change with time. Relationships can occur in multiple or single dimensions. An example of a multiple dimension relationship is speed with distance and time representing the two dimensions. Single dimension relationships can only be expressed relative to something else as in the location in space of some object. Its location can only be expressed with relative terms such as under, near, far etc.

**Competency indicators:**

- describe an object's position i.e., above, below, beside, etc., in relation to other objects.
- describe the motion, direction, spatial arrangement, symmetry, and shape of an object compared to another object.
- design patterns or interrelationship in a coherent manner and shape that promotes scientific appreciation and aesthetic sense.

5. Using numbers

Quantification refers to the process of using numbers to express observations rather than relying only on qualitative descriptions. The process has two major values. First, by expressing something in numerical terms the need for translation of verbal meaning is reduced. Second, the use of numbers allows mathematical logic to be applied to attempts to explore, describe and understand nature. The skill of using numbers is one application where one seeks precision of expression by transferring the logic of mathematics to qualitative problems.
Conceptual Review

**Competency indicators:**

- compute results from raw data.
- apply numerical values in place of variables and vice-versa to generate meaning.
- resolve theoretical dilemmas in an academic pursuit using mathematical figures of scientific significance.

6. **Communicating**

Communicating is the process of sharing information with others. Communication can take different forms: oral, written, nonverbal, or symbolic. Communication is essential in science, given its collaborative nature. This process actually refers to a group of skills, all of which represent some form of systematic reporting of data. The most common examples include data display tables, charts and graphs. Example: Describing the change in height of a plant over time in writing or through a graph. The process is conceptually fairly simple and is frequently based upon some type of two or three dimensional matrix with the axes representing the system variables and the cells of the matrix representing the interactions. The purpose of the communication skills is to represent information in such a way that the maximum amount of data can be reviewed with an eye toward discovering inherent patterns of association. Learners can use communication tools such as graphs, charts, maps, symbols, diagrams, mathematical equations, visual demonstration and written and spoken words to communicate vital information. The inherent nature of this process skill involves the ability to see and, consequently, represent information as the interplay among influencing variables.

**Competency indicators:**

- translate information into other forms such as graphs, tables and charts
- read information given in the form of graphs, tables, etc.,
- decide the best way of presenting information of a certain kind.
7. Predicting

The process skill of predicting deals with projecting events based upon a body of information. One might project in a future tense, a sort of trend analysis, or one might look for an historical precedent to a current circumstance. In either case, the prediction emerges for a data base rather than being just a guess. A guess is not a prediction. By definition, predictions must also be testable. This means that predictions are accepted or rejected based upon observed criteria. If they are not testable they are not predictions. The nature of the skill of predicting is to be able to identify a trend in a body of data and then to project that trend in a way that can be tested. Predicting is stating the outcome of a future event based on a pattern of evidence. Example: Predicting the height of a plant in two weeks time based on a graph of its growth during the previous four weeks.

*Competency indicators:*

- make use of evidences to formulate the sequence of a forthcoming process of action or outcome.
- use patterns or relationships to extrapolate to cases where no information has been gathered
- forecast events based on observations/previous experiences/ certain patterns of reliable data

8. Inferring

Inferring is an inventive process in which an assumption of cause is generated to explain an observed event. It is the process of drawing conclusions based on reasoning or past experience. This is a very common function and is influenced by culture and personal theories of nature. This is a process of concluding about the cause of an observation. Example: Saying that the person who used a pencil made a lot of mistakes because the eraser was well worn. Direct observation of objects or events enables people to suggest something, to interpret and explain things and
activities happening in their environment. For instance, an explanation or interpretation of an observation is indeed an inference (Funk et al., 1979).

**Competency indicators:**

- suggest explanations for events based on observations.
- analyse the cause and effect of decisions
- organize the observed data in a logical sequence leading to possible solutions.

**Integrated Science Process Skills**

9. **Identifying and Controlling variables**

Fraenkel and Wallen (1996) point out that “a variable is a concept, a noun that stands for variation within a class of objects, such as chair, gender, eye colour, achievement, motivation, or running speed”. It is something that can vary or change (Rezba et al., 1995; Fraenkel & Wallen, 1996;). The process skill of Identifying and Controlling variables necessitates the identification of the various dependent and independent variables during an investigation and to control them in due course of the investigation. It looks for the ability to identify variables (recognizing the characteristics of objects or factors in events) that are constant or change under different conditions, and that can affect an experimental outcome keeping most constant while manipulating only one (the independent) variable.

Example: Realizing through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans (Padilla, M.J, 1990). The process is an attempt to achieve a circumstance or condition in which the effect of one variable is clearly exposed. The use of experimental and control circumstances, standardizing procedures and repeated measures are only a few of the ways in which variables might be controlled. Understanding the nature of the skill requires analytical thinking in which the system under study can be reduced to a set of interacting components.
The next step is to establish some circumstance that allows to observe one component in isolation.

**Competency indicators:**

- identify the manipulated (independent) variable, responding (dependent) variable, and variables-held-constant in an experiment.
- identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable.
- identify the variables that may affect the dependent variable as stated in a problem.
- assign the limits of control of the selected variable in an investigation.
- propose degree of freedom of variables in an experiment to test hypothesis.
- control the variable in an investigation

10. **Interpreting data**

This process skill refers to organizing and analyzing data that have been obtained by collecting bits of information about objects and events that illustrate a specific situation, and drawing conclusions from it by determining apparent patterns or relationships in the data. Example: Recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables. Obviously, there is a direct contribution of the basic process skill of communication, to interpreting data. The better the data is represented the more likely one will detect associations within the data. Interpretation probably requires creative thinking that results in the invention of conceptual umbrellas that can encompass the data (Jerry Jinks, 1997).

**Competency indicators:**

- identify the relationship between the variables, from a given graph/table of data (relating to an investigation)
• draw conclusions from the data by determining apparent patterns or relationships in it
• form a reasonable conclusion which relates trends in the data to variables.

11. Formulating hypothesis

An inquiry involves an investigation of a question, a problem or an issue. This entails an investigator striving to obtain a solution to the problem. Finding a solution to the problem involves decision-making (Lambert & Balderstone, 2000). Before an inquiry is conducted, the investigator should suggest tentative answers to the problem. These tentative solutions are hypotheses (Gay & Airasian, 2000; Fraenkel & Wallen, 1996; McMillan & Schumacher, 1997). Hypotheses are predictions about the relationships between variables (Rezba et al., 1995). They guide the researcher with regard to which data to gather. The gathered information should be used to make the best educated guess about the expected outcome of the investigation (Martin et al., 1994). Example: The greater the amount of organic matter added to the soil, the greater the bean growth. The nature of the skill is to recognize that objectively gathered observations are justified into an explanation as a result of having an operational cosmology, or worldview. Secondly, a good hypothesizer recognizes that explanations are inventions rather than discoveries and that they are subject to rejection based upon facts.

Competency indicators:

• identify questions or statements which can and cannot be tested
• design statements, i.e., questions, inferences, predictions, which can be tested by an experiment
• state the expected outcome of an experiment
• develop testable explanation
• explain a given observation in terms of conceptual relationships
12. Defining operationally

A definition that attributes meaning to a concept by specifying the procedures that must be conducted in order to measure or manipulate the concept, is an operational definition (Ary, Jacobs & Razavieh, 1990; Borg & Gall, 1989 McMillan & Schumacher, 1997). Variables can be defined operationally by applying some kind of a measurement (a measured operational definition) or by listing the steps taken in an experiment to produce research conditions (an experimental operational definition) (Ary et al., 1990). An operational definition is one that is made in measurable or observable terms. An operational definition should not require interpretation of meaning nor is it relative. The meaning of the defined term must be explicit and limited to the parameters established for the definition; stating how to measure a variable in an experiment and defining the variable according to the actions or operations to be performed on or with it. Example: Stating that bean growth will be defined as the amount of change in height as measured from the top of the soil to the tip of the longest stem in centimeters per week. An operational definition is primarily a research tool and related to the concern for controlling variables. The major function of operational definitions is to establish the parameters of an investigation or conclusion in an attempt to gain a higher degree of objectivity.

**Competency indicators:**

- state how to measure a variable in an experiment
- define the variable according to the actions or operations to be performed on or with it
- formulate a meaningful statement that generates a sense of understanding

13. Experimenting

An opportunity to practice all the science process skills, that have been discussed, is provided by experimenting. Experiments are a way of learning something by varying some conditions and observing the effect on something else
An experiment is a scientific investigation in which the researcher controls some independent variables and observes the effects of these manipulations on the dependent variables (Ary et al., 1990). The investigator starts with a question which needs to be solved. The first step to find solutions to the problem will be to identify the variables, to formulate the hypotheses, to identify the factors that should be held constant, to define variables operationally, to design an investigation, to rerun trials, to collect data and then interpret data (Ary et al., 1990; McMillan & Schumacher, 1997; Rezba et al., 1995). All these activities include the science process skills that have been discussed earlier. Experimenting is a systematic approach to solving a problem. Usually experimenting is synonymous with the algorithm called scientific method. The purpose of the process is to judge the extent to which a hypothesis might be true and to set a standard whereby that judgement is made. Experimenting includes being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the effect of organic matter on the growth of bean plants.

**Competency indicators:**

- identify what is to be measured or compared in a given investigation
- select a suitable design for an investigation to test a hypothesis
- recognize limitations of methods and tools used in experiments, i.e. experimental error.
- utilize safe procedures while conducting investigations
- using appropriate apparatus

The above basic and integrated science process skills are schematically represented in the following diagrams 2.1 and 2.2.
How do children acquire these skills?

What these processes might mean in terms of the child’s way of working can be explained as:

- Observing - looking, listening, touching, tasting, smelling
- Asking the kind of question which can be answered by observation and fair tests
- Predicting what they think will happen from what they already know about things
- Planning fair tests to collect evidence
- Collecting evidence by observing and measuring
- Recording evidence in various forms - drawings, models, tables, charts, graphs, tape recordings, data logging
- Sorting observations and measurements
- Talking and writing in their own words about their experiences and ideas
- Looking for patterns in their observations and measurements
- Trying to explain the patterns they find in the evidence they collect

The science teacher’s role

The science teacher has a vital role in this process and this can be developed by:

- Helping pupils to raise questions and suggest hypotheses
- Encouraging children to predict and say what they think will happen
- Encouraging closer and more careful observation
- Helping children to see ways in which their tests are not fair and ways to make tests fairer
- Encouraging pupils to measure whenever it is useful
- Helping pupils to find the most useful ways of recording evidence so that they can see patterns in their observations
- Encouraging children to think about their experiences, to talk together and to describe and explain to others
- Helping children to see the uses they can make of their findings
Viewing science as a “way of thinking” or as a “way of investigating phenomena” supports the notion of finding a logical and rational balance between the importance of facts, concepts, principles, laws, hypotheses and theories, and the premises supporting a methodology that could be followed in the exposition of new and creative assumptions and rational arguments. The science process skills fit this premise of understanding and collectively contribute to the establishment of the skills as operational outcomes whose mastery should be regarded as foundational to all learners’ understanding of science. While it is desirable that children acquire these skills, it must be said that it is unlikely that any of these skills can be taught or acquired in isolation, but are involved and developed through many, if not all science activities.

Educational systems are currently undergoing transformational changes throughout the globe and one of these is a shift from a philosophy that focuses mainly on the transmission of information to an understanding that supports the constructivist paradigm of teaching and learning. As the global population crosses the seven billion milestone, due importance on the acquisition of science process skills serve as a conceptual paradigm of fostering education for global excellence.

(C) THE SCIENCE LEARNER

"You cannot teach a man anything; you can only help him find it within himself." - Galielo Galilei

The process of learning began and evolved with man. Man is different from other creatures because he is able to manipulate his circumstances and construct what he requires from nature. The process of learning is as important as the content of learning. The learners have the natural ability to formulate their own inferences and theories about nature, themselves and their relationships with others. Science, in a broader sense, is the comprehensive knowledge hitherto collected as well as the processes by which this knowledge is created. Learning of science deals with the discovery of new knowledge, making use of the acquired knowledge and methodology.
The success of a learner is dependent on a combination of many factors. There is no "one-size-fits-all" rule to academic achievement. Various factors in and out of the school and personal characteristics affect the learner’s achievement in science. The learner characteristics include motivation, intelligence, attitude, aptitude, interest, future aspirations, etc. Factors within the school include instructional variables such as methods of teaching, type of curricular and co-curricular experience provided in the school, teacher-pupil relationship, peer interaction, classroom environment, etc. Out-of-school experiences include those socio-familial variables like parent’s income, cultural level, home environment for study, facilities at home, parental aspirations, attitude of the parents towards education, etc. (Asmali, 1994)

The influence of the select context variables—science instructional, motivational and familial—on the acquisition of science process skills and achievement in science is explored in the present study. The three select context variables are schematically represented in the following diagram 2.3

Diagram 2.3
Classrooms are conceived as a cohesive community of learners which embodies ‘a culture of learning in which everyone is involved in a collective effort of understanding’ (Bielaczyc & Collins, 1999). The 21st Century classroom is perceived as pupil-centered, not teacher centered. Teachers no longer function as lecturers but as facilitators of learning. Learners of today differ from those of the past. Engaged, motivated, self-directed, and diverse learning styles characterize contemporary learners. Today’s learners are wealthy in terms of access to media and communication, and they demand engagement in everything they do (Prensky, 2005). They want to be able to connect their learning to the here and now. They want to know how the learning they are engaged in will help them later on in their lives.

The science instructional variables at school play an important role in determining the achievement in science of the learner. Lower (2008) states that the new generation of learner prefers learning environments that are structured, fast moving and infused with technology. Thus, to meet their needs, teachers have to engage them in learning that mirrors the world they experience outside the classroom. (Prensky, 2008).

Curiosity is the normal response of the infant and young child to novelty (Trudewind, 2000). In the early years of schooling this is a very strong motivation for information seeking and knowledge acquisition. For young children, the learning experiences they encounter in school are new and unfamiliar and so it is likely that their interest will be aroused. They engage with the activity, they explore it, try out what can be done, and in the course of all this activity they expand their knowledge. When a learning activity arouses curiosity and students engage with it, the activity can be described as intrinsically motivating. Across the course of schooling, it is noted that activities do not arouse curiosity to the same extent as that is observed in younger children. Students’ developing patterns of personal or individual interests contribute to this change. Driscoll (2005) says “Motivation is often inferred from learning, and learning is usually an indicator of motivation”. It is the obligation of the science teacher to create and sustain a science classroom.
that promotes high levels of student motivation and engagement. Innovative instructional strategies that can trigger the intrinsic motivation of the learner, further lead to a love for the subject, contributing to its achievement of knowledge and skills.

Young students’ curiosity and wonder about the world around them provides the basis for building strong patterns of personal interest that will support learning through adolescence. When students have well-developed personal interests that are compatible with the activities and experiences encountered in their classrooms, they will readily engage with those activities and will expand their knowledge and understanding (Renninger, 2000). Many of the activities and experiences that are required within the school curriculum may not trigger curiosity and so do not directly activate information seeking or the development of competence. It is essential that student’s motivation to learn science be assessed and fostered in introductory high school science courses. The motivation to learn science can lead students to scientific literacy to understand scientific knowledge, identify important scientific questions, draw evidence – based conclusions, and make decisions about how human activity affects the natural world.

Driscoll (2005) mentions that individual and personal curiosity often motivates people and piques their interest. Learners are also more apt to be motivated if the instruction involves a variety of ways of presenting information or fantasy. Learners also respond well to situations that involve problem solving. Learners who are motivated to learn science and engage in science-learning behaviour pursue goals such as good science grades and science-related careers. Hence, in this information-rich society, the learners’ cognitive processes such as curiosity, interest, goal orientation and self-efficacy must be deliberately imported into the structure of the classroom to enhance their achievement in science.

Inquiry is the process scientists use to build an understanding of the natural world based on evidence. Learners can arouse curiosity and learn about the world using inquiry. Although learners rarely discover knowledge that is new to humankind, current research indicates that when engaged in inquiry, learners build
knowledge new to themselves. Learner inquiry is a multifaceted activity that involves making observations, posing questions, examining multiple sources of information to see what is already known, planning investigations, reviewing what is already known in light of the learner's experimental evidence, using tools to gather, analyzing and interpreting data, proposing answers, explanations, and predictions and communicating the results. Thus instructional variables—methods of teaching, type of curricular and co-curricular experience provided in the school, teacher-pupil relationship, peer interaction, classroom environment, etc., contribute largely to the acquisition of the science process skills and better achievement in science.

According to a family research project conducted by the Harvard Graduate School of Education, children whose parents maintain consistent involvement in their children’s education are more likely to succeed academically. Some of the key components of parental involvement noticed in the study were communication with the child, emphasis put on reasonable academic expectations, reading together and attendance at school functions, events and meetings. Parental support is very important when it comes to student achievement. The more support students have from their families, the easier it is to attain higher achievement.

Achievement is the result of a conscientious effort made by the learner, with honest support from parents, teachers and the society at large. Hence, due emphasis needs to be given to the school, personal and home factors, to improve the achievement level of the students in science.

(D) THE SCIENCE TEACHER

“Every truth has four corners: as a teacher I give you one corner, and it is for you to find the other three” - Confucius

Teaching itself is a demanding and complex task, while science teaching is a challenge. Teaching becomes a profession when teachers practice with a common knowledge base and apply their knowledge to effective practice (Wise & Leibbrand,
The best teachers tend to be goal-focused, but flexible and reflective. These characteristics allow them to relate to students and to modify and improve their practices. Teachers of science need to strive continuously to grow and change, personally and professionally, to meet the diverse needs of their students, school, community, and profession.

Education is a discipline aiming at revealing systematic and scientific results towards meeting the needs of individuals and society. Schools used to be the source of knowledge, a place where children were educated more or less without parental control. Schools used to prepare learners for examinations and thus, teaching was mostly exam preparation or exam training especially at the secondary school level. In the past, teachers used to be lecturers- the major source of knowledge, the leader and educator of their students’ school life. Teachers in the modern classrooms are no longer lecturers, they are facilitators, their main task is to set goals and organize the learning process accordingly. They are supporters rather than educators.

Teachers are responsible for operating the educational system and they need strong and efficient professional competencies. Competencies are defined as “the set of knowledge, skills, and experience necessary for future, which manifests in activities” (Katane et al., 2006). Gupta (1999) defines competencies as “knowledge, skills, attitudes values, motivations and beliefs people need in order to be successful in a job.” The concept of teachers’ competencies is mostly discussed in relation to teachers’ teaching duties in the school. In this respect, teachers’ competencies need to be discussed in many dimensions such as field competencies, research competencies, curriculum competencies, lifelong learning competencies, social-cultural competencies, emotional competencies, communication competencies, information and communication technologies competencies and environmental competencies.

“The art of teaching is the art of assisting discovery” (Mark Van Doren). Science teaching is a composite profession requiring knowledge and skills in both
science and education. It is generally recognized within the professional community that science content expertise alone is not sufficient to define a good science teacher. Hence, content has to be operationally defined to include the knowledge and skills that are learned, or should be learned, in the course of the science teacher education curriculum. This includes important scientific concepts and relationships, applications of science in technological contexts, mathematical skills and applications, methods and processes of conducting true scientific investigations, knowledge and skills related to the nature of science, issues and community might also be addressed in science teacher’s content preparation. The science teacher needs to be prepared to effectively engage students in concrete manipulative activities that will lead to the development of desired concepts through investigation and analysis of experience (NSTA, 2003).

What are the characteristic features of good or bad teachers/teaching? This is an evergreen question which often cannot be answered without understanding the real contexts of teaching. However, researchers have examined and described the different components of teachers’ knowledge (like Roberts 1998), the characteristic features of teachers (Hargreaves & Fullan: 1992, Falus: 1998). They have come up with the importance of content knowledge (teachers’ subjects), pedagogic content knowledge (how to adapt content to the learners), general pedagogic knowledge (e.g. classroom management), curricular knowledge, contextual knowledge (the context of teaching: community expectations) and process knowledge (learning skills, observation skills, etc.). Among the characteristic features, cooperation, flexibility and the ability to relate learners appear rather important. Science teachers need to improve knowledge and skills to enhance, improve and explore their teaching practices. The science teacher who mirrors the following expected instructional preferences is the need of the hour.
Science Teacher Instructional Preference Categories

An attempt has been made to explore the science instructional preferences of science teachers so as to stimulate a learner-centred science classroom to accomplish the expected science learning outcomes. The ten science teacher instructional preference categories, as envisaged in the study are schematically represented in the following diagram 2.4
a) Teacher- Pupil Interaction Dynamics (TPID)

The success of school life largely depends on the teacher-pupil interaction and cohesive interpersonal relationships. Proper attention must be paid by a teacher as a professional on the evolution of a strong teacher-pupil-teacher relationship. A common approach by which a teacher can initiate the interaction in a classroom is by asking questions. The communication between the student and the teacher serves as a connection between the two, which provides a better atmosphere for a classroom environment. Pianta (2009) points out that the development of students’ cognitive and affective competencies largely depends on the quality of teacher-pupil interaction. Not only proper communication, but meaningful feedback and assessment mechanism also must form part of an efficient interaction mechanism in a class.

b) Influence of Life-Skill Integration (ILSI)

The World Health Organization has defined life-skills as, "the abilities for adaptive and positive behaviour that enable individuals to deal effectively with the demands and challenges of everyday life. UNICEF defines life-skills as “a behaviour change or behaviour development approach designed to address a balance of three areas: knowledge, attitude and skills. Life-skills are essentially those abilities that help promote mental well-being and competence in young people as they face the realities of life. Life-skills include the skills the student needs to be successful in society. Most development professionals agree that life-skills are generally applied in the context of health and social events. Teaching life-skills is an important part of an education, especially at the secondary level where the learners are in their adolescent stage. Life skills empower young people to take proactive action to protect them and promote healthy and desirable social relationships. With proper orientation in life skills, the pupil will be able to explore alternatives, weigh pros and cons and make rational decisions in solving each problem or issue as it arises. Without life-skills, students will not be able to apply what they have learned at school, to their everyday life. Developing life-skills helps adolescents to translate
their knowledge into proper actions, attitudes and values into healthy personal and social behaviour, enthusiasm and emotional integrity to prioritizing of their needs and wants. The science teacher is always to be ready to extent a helping hand to students to learn how to take better care of them by incorporating awareness on life-skill applications through their lessons. Thus training in life-skills must form an indispensable part of teacher activities in schools.

c) Flexible cum Viable Instructional Strategy Integration (FISI)

Teachers of science aim to create a community of diverse learners who construct meaning from their science experiences and possess a disposition for further exploration and learning. For this, science teachers have to provide learning experiences through multiple styles of interactions strategies. The many modes of classroom interaction styles adopted by a science teacher makes use of the possibilities of techniques and tactics like questioning, discussing, solving problems, inquiring, field trips, projects, brain-storming, concept mapping, model building, role playing, game-playing, simulating, electronic media, written reporting of investigative techniques and data, cooperative and collaborative learning (NSTA, 2003). The NSTA expectation is that science teachers are able to design and practice instructional strategies much beyond the scope of the above said items. With the increasing use of personal computers in schools, homes and workplaces, and internet connectivity, Information and Communication Technology (ICT) shows renewed promise as a powerful tool for science education. Teach also must acquire talent and interest in the design and use of e-content suitable for the twenty first century learners.

d) Process Skill Application in Procedures (PSAP)

Teachers of science have to engage students both in studies of various means of scientific inquiry and in active learning through scientific inquiry. They have to encourage students, individually and collaboratively, to observe, ask questions, design inquiries, and collect and interpret data in order to develop
concepts and relationships from empirical experiences. Teachers who use inquiry effectively tend to be more indirect, asking more open-ended questions, leading rather than directing, and stimulating more student-to-student discussion (Brophy & Good, 1986). In general, the younger the child, the more concrete the inquiries should be. Students who learn through inquiry gain a deeper understanding of the resulting concepts than when the same concepts are presented through lecture or readings. This has led to the principle that less is more: Teaching fewer concepts with greater depth will result in better long-term understanding than covering many concepts superficially. In addition, students will gain the skills of inquiry and scientific attitudes and gain greater knowledge of how scientific research is actually conducted (NSTA, 2003). A strong faith and practice in process oriented teaching and learning has to become the cardinal philosophy that guides the whole actions of a science teacher in and outside the classroom.

e) Adaptation of Multi-Pronged Assessment Techniques (AMAT)

Instruction and assessment must be practiced collaterally by a teacher to realize meaningful classroom interaction patterns. Teachers of science need to construct and use effective assessment strategies to determine the achievement and progress of learners. They have to assess students fairly and equitably using multiple assessment tools and strategies to achieve important goals for instruction that are aligned with methods of instruction and the needs of students, use those results to guide and modify instruction and to use them as vehicles for engaging students in reflective self-analysis of their own work. It is "assessment that mirrors and measures students' performances in 'real-life' tasks and situations" (Hart, 1994, p, 106). Good assessment strategies help students learn about their strengths and weaknesses. Variety in assessment strategies doesn’t include implementation of varied kind of traditional and modern assessments tools alone. But a comprehensive coverage of assessment of various faculties of human development - cognitive, affective and psychomotor - must be possible through the assessment techniques at hand. Possibility of peer assessment could also be explored. According to AAAS (1997) contemporary
teachers are expected to feel confident in using authentic assessment to measure achievement of science standards and benchmarks spread over the scholastic and co-scholastic components of school experiences.

f) Technology Wowed Procedural Enrichment (TWPE)

A single development and invention in science and technology at a far distant place has an unprecedented influence even in our locality. Distance and time are two variables to be visualized and operated from a different perspective today than before a quarter of a century ago. The science classroom environment is also not an exception to this phenomenon. The information overflowing in a science learning context of today’s schools is a matter to be approached with caution and new generation skills. The challenges posed by technology can be resolved only through technological tools. Science teachers have to access common sources of information (newspapers, magazines, televised reports) to relate their science instruction to contemporary issues and events. They need to know how to effectively use various resources such as news media, libraries, resource centers and the Internet. Science teachers in the modern technological world should know how to use appropriate technology including, but not limited to, computers and computer peripherals, both to enhance learning and to relate the use of technology to science. In addition to using technology in the science classroom, teachers also have to ensure that students understand the role technology plays in professional science. Science teachers should know how to effectively use various resources such as news media, libraries, resource centers and the Internet. The emerging practice of edutainment and edupreneurship must be well acquired by the science teachers of today.

g) Professional Growth and Auto- Empowerment (PGAE)

A desire for continued professional growth and auto-empowerment is an essential quality for effective teacher performance. The urge of a science teacher who earnestly engages in self-competency enhancement activities is
demonstrated by his/her participation in professional enhancement programmes and related avenues. Reflective practices aiming at leadership quality exhibition resulting in performance level which goes beyond minimum level of work requirements is largely expected from science teachers of the contemporary age. Adoption of appraisal strategies like Peer and Student Evaluation procedures and self evaluation through journaling are essential for enhancing professional competencies. As Sergiovanni (1992) suggests, exemplary processes for growth must have an amalgamation of technical skill enhancement with a one set of professional virtues. Converting the latest research in the field to practice, an inquiry through novel experimentations in the field and collaborative discussion of findings and experiences with peers and collaborating stakeholders are characteristics of the much needed professional growth and self-guided empowerment of science teachers of the twenty-first century. This in turn requires many folded opportunities for reflective actions in the context of real life experiences as argued by Choudhury and Roth & Ebbing (1993).

h) Adoption of the Spirit of Inter-Disciplinarity (ASID)

Inter-Disciplinarity and collaboration are the thumb rules of classroom practices today; not only in Sciences but in all branches of knowledge. Interdisciplinary teaching is a method, or set of methods, used to teach a unit across different curricular disciplines. No subject can be taught in isolation. Interdisciplinary/cross-curricular teaching provides a meaningful way in which students can use knowledge learned in one context as a knowledge base in other contexts in and out of school (Collins, Brown, & Newman, 1989). It increases motivation for learning and their level of engagement and also provides the conditions under which effective learning occurs. Correlation enables a child to comprehend better the meaning of what he studies. Conceptual clarity and effective structuring of knowledge are easily achieved through inter-disciplinarity and correlation. The pathways of correlation that a science teacher is expected to utilise in his/her class are (1) correlation within science (2) correlation among the
different subjects (3) correlation between the science and life outside. Science teachers must strive for maximum degree of correlation which makes the teaching-learning process more realistic and interesting.

i) Preference for Quality of Life Enhancement (PQLE)

Science is a powerful tool of social change and cultural modification. Hence learning of science must pave way for social revolution and reduction of socioeconomic divide. Training in healthy practices of life leading to social harmony and sustainable development must begin from science classrooms. Fighting against social evils of untouchability and discrimination based on caste, language, religion, colour, creed, gender and geographical location – are to be practiced by the science teachers in their classrooms. Hence science teachers are expected to be models of Scientific Attitude. Imparting an awareness among the learners about the interface of science, technology and society, sensitizing them, especially to the issues of environment and health, and enabling them to acquire practical knowledge and skills to enter the world of work also form part of the greater responsibly of a twenty-first century science teacher. The awesome responsibilities of a science teacher as a career guru and lifestyle consultant for the new generation learners are widely recognized.

j) Styles of Meta-Cognitive Strengthening (SMCS)

Meta-Cognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them. Quite simply, meta-cognition is thinking about thinking; which leads one to academic success and problem solving ability (Theide et al., 2003). Any process in which students examine the method that they are using to retrieve, develop or expand information is deemed to be metacognitive in nature. Hence the style and practice of interaction by a science teacher must give due consideration to the metacognitive strengthening of learners’ abilities and potentialities. Rather than helping the students to arrive at fixed answers as solutions to the stimuli provided by the teacher; they must be
encouraged to probe into various options of responses through critical thinking. Facilitating creative expressions will help the students to be more and more independent learners and problem solvers. Acquaintance with investigative encounters using issue-based problem solving strategies and familiarization of routes of learning how to learn science rather than memorizing the product of science will contribute much in the metacognitive strengthening of learners.

Thus, a generation of teachers who aim to develop learners instead of teaching them, who help their pupils to become independent learners, who provide students with motivation and interest for life-long learning and urge them to become autonomous learners, is essential to meet the new demands in education.