CHAPTER - I
INTRODUCTION

1.1 IMPORTANTCE OF SCIENCE

Science and technology have profoundly influenced the course of human civilization. Science has provided us remarkable insights into the world we live in. The scientific revolutions of the 20th century have led to many technologies, which promise to herald wholly new eras in many fields. As we stand today at the beginning of a new century, we have to ensure fullest use of these developments for the well being of our people.

It is commonly felt that a child's education cannot be completed unless he has some knowledge of science irrespective of the field of study he wishes to pursue in later life. In this present scientific age, when man is galloping in the space age, discovering the secrets of nature, when science has been providing material, convenience and comforts to man and when the creations of science have been doing the job of men, thinking on behalf and even taking decisions on behalf of men, it is absolutely necessary that each and every individual should acquire a minimum general knowledge of science for his own survival as an individual and to make himself useful to the present society. Today, science has permeated through the human life in such a way that it has now become every man's every day concern. It has reached the common people and as such learning of science must now reach the masses.

The rapid advancement of science and technology and increasing need for scientists and technologists have made it all the more important to provide for science based education in the schools. So, science is included in the school curriculum for the same reasons as any other subject, but in addition, science inculcates certain special values peculiar to objectives and rational outlook, which no other subject can provide. Besides this science learning provides training in scientific method and helps to develop a scientific attitude of mind in learners. Science teaching makes a specific impact on the lives of the children and this impact is on the positive side of the goals of education in the socio-economic and cultural context of the society.
Science and technology have been an integral part of Indian civilization and culture over the past several millennia. Few are aware that India was the fountainhead of important foundational scientific developments and approaches. These cover many great scientific discoveries and technological achievements in mathematics, astronomy, architecture, chemistry, metallurgy, medicine, natural philosophy and other areas.

Jawahar Lal Nehru as prime minister of India for seventeen years since the beginning of independence molded the character of modern India because of his great zeal for science and scientific attitude. Pandit Nehru sent a message to the Silver Jubilee Session of the Indian Science Congress at Calcutta that: "It is science alone that can solve the problems of hunger and poverty, of insanitation and literacy, of superstition and dreading customs and traditions of vast resources running waste of a rich country inhabited starving people. Even more than the present the future belongs to science and those who make friends with science (Sikka, 1993).

Shri Atal Bihari Vajpayee (2003), who gave the slogan – Jai Jawan, Jai Kissan and Jai Vigyan, said "We must take science to the people. Let us also remember that a bright future can be realized only when science is in league with the majority of our society".

Dr. Murli Manohar Joshi (2003) Minister for Human Resource Development, Science and Technology and Ocean Development while framing Science and Technology Policy in 2003 said, "Our new policy is anchored in our abiding belief that for science and technology to grow, it must have a human face, it must be gender sensitive, it must be region and context specific, reflect our enormous diversity and plurality, and it must empower the community as a whole and not merely a section of it".

The importance of science as a school subject can be depicted from the views of various commissions:-

Secondary Education Commission-(1953) has recommended, "Every secondary school pupil should study general science as a compulsory subject so that he gains a basic quantum of science knowledge as a part of his general education."

The Scientific Policy Resolution of the Government of India, (1958) stated – "The dominating feature of the contemporary world is the intense
cultivation of science on a large scale and its application to meet the country's requirements.

Kothari Commission (1964-66) stated that: "The progress, welfare and security of the nation depends critically on a rapid, planned and sustained growth in the quality and the extent of education and research in science and technology.... there is, of course, one thing about which we feel no doubt or hesitation: education, science based and in coherence with Indian culture and values, can alone provide the foundation as also the instrument for the nation's progress, security and welfare".

Indian Education Commission (1968) has recommended - "If science is to be pursued with full vigor and zest and is to become a mighty force in Indian renaissance, it must derive its nourishment from cultural and spiritual heritage and not bypass it. Science must become an integral part of our cultural fabric."

UNESCO's International Education Commission (1972) recommended - "Science and technology must become essential components in an educational enterprise; they must be incorporated into all educational activity intended for children, young people and adults, in order to help the individual to control social energies as well as natural and productive ones, thereby achieving mastery over himself, his choices and actions and finally, they must help man to acquire a scientific turn of mind so that he becomes able to promote science without being enslaved by it."

National Policy on Education (1986) has given the recommendation as under - "Science education will be strengthened so as to develop in the child well defined abilities and values such as the spirit of enquiry, creativity, objectivity, and the courage to question and an aesthetic sensibility."

If our country is to keep in step with rapidly changing world;

- Firstly, our schools must be able to prepare students who can master efficiently the latest developments in all fields of science and technology being discovered every year.
- Secondly, our school curriculum should adhere scientific values to enhance the pragmatic attitude among the pupils
Thirdly, secondary school is an appropriate stage for the initiation of the future scientists, so it is essential that the teaching of science must have a prominent place in the secondary schools of our country.

The primary objective of science teaching is to give knowledge and information about the world we live in. Specifically, the basic aim of science teaching, especially in elementary schools is to supply fundamental knowledge of science which may be brought in to use at the daily environment through the study and application of science, to achieve that more emphasis is given to the comprehensions of the fundamentals and processes of science as against memorization. It brings the holistic view of science which includes:

(a) Concepts in science
(b) Processes in science
(c) Social and cultural aspects of science
(d) Moral and ethical aspects of science.

So, the teaching of science from the elementary level itself should encourage the permeation of the spirit of science as a way of thinking (Punjab Education Policy, 2002).

Professor Yashpal (1992) is of the opinion that, instead of considering science as an extraneous activity or as a tool for providing the means to a good life, usually borrowed from outside, we should treat it as a part of the culture of society, integral to our living and thinking and connected to the deepest questions we ask in regard to who we are and where we come from.

The Columbia Encyclopedia defines science as "an accumulated and systematized learning, in general usage restricted to natural phenomena". Science is not just a collection of some isolated and assorted facts and principles. Moreover, knowledge is not static. It may change its meaning and importance with time. Science, to be meaningful and valuable, should be taught as a whole, at the school stage. The facts and principles of science should, as far as practicable, be taught as generalized concepts (Vaidya, 2003).

Since science has become a part of contemporary culture, we must teach science to all the citizens as part of general education to provide the learners with common interests, knowledge and skills for effective participation in the developmental activities in our democratic society.
secondary level, science as a discipline of the mind and preparation for higher education deserves special emphasis.

There are four pillars of education, (i) Learning to know, (ii) Learning to do, (iii) Learning to live together, (iv) Learning to search for inner self (UNESCO Report on Education In 21st Century). But, to achieve it we will have to humanize our science education and make it relevant to the pupil’s real world which may envisage development of science curriculum on the basis of the life experiences. The primary task of science education must include the transaction of activities, which need be simple, clear and unequivocal, so as to eliminate doubt, uncertainty and difficulty. Secondly, it conducts tests which aim at discovering what the students actually know and how far they are capable of applying the knowledge in their lives and activities.

So, if we have students coming out of the school system with a strong science foundation, in the long run we have a technologically oriented nation, which is able to harness science and technology in every aspect of life, at work and in the homes. To enhance the international competitiveness of the country, it is therefore, critical for us to promote science and technology in the education system. Science and technology are at the heart of the development of human societies particularly the disadvantaged sections of the society, in creating wealth for all, in making India globally competitive, in utilizing natural resources in a sustainable manner, in protecting the environment and ensuring national security.

1.2 SCIENCE LEARNING

Science is a great human enterprise, not only endless and faceless, but also stable and fluid. It is self accumulating, self growing, self-accelerating, self-pervading and self corrective enterprise, which originated in the collective curiosity of man since time immoral. It is a body of knowledge that allows us to comprehend the laws that govern everything in nature, from the galaxies to the atoms, from the non-living to the living. Science is an esoteric activity, as it requires a high level of specialization and creativity and involves complex concepts (Bhargava and Chakrabarti, 2006).
James, B. Contant as given by Bhandula (1989) has defined science in the following words. “Science is an inter-connected series of concepts and conceptual schemes that have developed as a result of experimentation and observation and are fruitful of future experimentation and observation.

Learning is simply the process of adjusting our mental models to accommodate new experiences. The National Curriculum Framework (NCF) developed by National Council of Educational Research and Training (NCERT) in 2005, recommends a paradigm shift from rote memory to learning by understanding. In general science offers pupils with learning opportunities to:

- Develop an awareness of, and, interest in themselves and their immediate surroundings and environment.
- Join in practical activities that link to ideas, for example, doing and thinking.
- Use their senses to explore and investigate.
- Develop an understanding of cause and effect.

In response to these opportunities, pupils can make progress in science by understanding the links between cause and effect, increasing their experience, knowledge and understanding and applying it to everyday life. But students often consider science to one of the most difficult subjects they take, because of its perceived difficulty many students even develop science phobias.

According to report of Education Commission (1964) – “If science is poorly taught and badly learnt it is little more than burdening the mind with dead information and could degenerate even into a new superstition.”

The UK has a long tradition of educating and training scientists, engineers and mathematicians who have contributed greatly to the economic stability of the nation. However, even though more young people are entering higher education, fewer students are choosing mathematics, physics and chemistry (HESA, 2005), resulting in a skills shortage. The key to reversing this trend is to inspire and enthuse young people in science and engineering throughout their school education. Mathematics and the physical sciences, however, lack positive role models and effective careers advice for aspiring students (Roberts, 2002; Rasekoala, 2001).
A survey of 50 schools across the UK showed that although most students enjoyed learning science at school, few wanted to study science after school (Bevins et al., 2005).

So it is important to create a learning environment in the classroom where students can make sense of science and use science to make sense of the world. Now National Curriculum Framework (NCF) has suggested a paradigm shift from 'transmission of knowledge by the teacher to construction of knowledge by the learners.'

1.2.1 Constructivism

Constructivism is a general name given to the dominant perspective on learning and especially in science education. "I hear and I forget, I see and I remember, I do and I understand." is the familiar phrase which shows the intent of Constructivism. It is the philosophy founded on the belief that we construct our own understanding of the world by reflecting on our experiences. Each of us generates our own ‘rules’ and ‘mental models’ which we use to make sense of our experiences. This perspective is developed from the research theories of Piaget (1970), Vygotsky (1986), and philosophy of John Dewey (1938). According to constructivism, learning is:

- Not a passive receptive process but is instead an active meaning making process required to solve meaningful problems.
- New learning depends on learner’s previous knowledge.
- Learning implies reorganization of prior conceptual scheme or cognitive map.
- Learning is facilitated by social interaction (i.e. interaction between learner and teacher and amongst learners) (Sharma, 2005).
- Learning is contextual: we do not learn isolated facts, we learn in relationship to what else we know, what we believe, and what we feel.
- Learner actively constructs knowledge and strives to make sense of the world through personal experiences, goals, curiosities and beliefs (Sood, 2006).

In reality learning is process of construction and reconstruction of knowledge (Khader, 2005). Learning is an internal process and influenced by the learner’s personality, prior knowledge and learning goals (Davidson, 1995). So, learning is the result of a learner’s mental constructions. A learner
learns by fitting new information together with what he/she already knows and actively constructs his/her own understanding.

In fact learning is a process how the learner arrives at a particular answer. It is the process of building conceptual structures through reflection and abstraction (Von Glasersfeld, 1995) and the foci are on the concept development and understanding (Fosnot, 1996). In the same way the major goal of science instruction in the secondary schools is the development of conceptual understanding. Throughout our instructional arrangements we intend to organize examples and situations in such a way that the learner will be able to acquire the concepts (Pandey, 1983).

The structure of science can be compared to the framework of a building under construction. A framework of a building consists of a foundation, vertical pillars and horizontal beams. The foundation of the framework is comparable to the concepts, broad generalizations and principles of science, the vertical pillars to theories and horizontal beams to methods of science. If the base (foundation) will be strong, the building in turn will also be strong. Science learning for most of the students involves the process of conceptual change (Kyle, 1989).

Traditionally, classroom experiences emphasise rote learning. But science education is now increasingly finding a base on constructivist, cognitive and social learning theories which consider a human being as an active constructor of knowledge rather than as being passive recipient of environment stimuli (Gupta and Rawat, 2003). Learning is characterized by a process of interaction between the student's mind and the stimuli providing new information. Such a learning environment enables students to modify their existing cognitive structures and to experience a dynamic interaction between their preconceptions and the appropriate scientific conceptions (Kyle, 1989).

According to Ausubel (1968), Piaget (1971) and Nurrenberg (2001) a learner organizes knowledge structures depending on his/her range of experiences through assimilation and accommodation. New knowledge is constructed by the learner through equilibrium between the above.
1.2.2 Conceptual Change Approach

Prior knowledge forces a theoretical shift to viewing learning as 'conceptual change' (Strike and Posner, 1985; West and Pines, 1985). The Learning Cycle has been used to structure science instructions in order to help students move from concrete experience to formal abstract thinking about content. This constructivist approach is in turn based on Piaget's theory of intellectual development. According to this, development is structured by three teaching phases: Exploration, concept invention/introduction and application. Through this sequence student's thinking is expected to progress from concrete thinking about science concepts to being able to deal with these concepts on a formal abstract level (Hartman, 2001). So engaging the students in a quest for knowledge to develop their rational power to think through this learning cycle and refine the everyday knowledge formed by observation of natural world was among the purposes of science education. This is called Conceptual Change Approach.

Following are the common grounds in view of science learning as a Conceptual Change Approach (Gil et al. 1994):

- An exploration phase of students' prior knowledge, making them explain their ideas and presenting them with events which change their ideas introducing cognitive conflict and explore the concept experimentally in as much detail as they can and relate to other experiences. The students interpret the results according to the plausibility and fruitfulness of the new ideas.
- A restructuring phase in which the students are introduced to the concepts in a way to expose them to statements of concepts and through scientific language. Teachers help them in interpretation of what they have found in exploration.
- The third phase provides the students further experiences with the concept to expand its meaning through application of newly learnt concepts to new situations.

The concepts give structure and order to the world around us. Smith and Medin (1981) stated that "Without concepts, mental life would be chaotic."
1.2.3 Meaning of Concept

According to the instructional design research as reported by Tennyson and Park (1980), a concept is assumed to be a set of specific objects, symbols or events which share common characteristics (critical attributes) and can be referenced by a particular name or symbol. Concept is the idea an individual has about a particular class of objects (including animated objects) or events, grouped together on the basis of the things they have in common. If these concepts of a child prove inadequate, he may have to modify them in one way or perhaps try to develop a new concept all together (Fontana, 1981).

Concepts are basic elements of thought. A concept is not observable. It cannot be an observable stimulus or a set of objects, or an observable response. Concept is the cognitive structure which each individual builds for himself in his continuous effort to impose meaning on/upon the chaotic world of his sense. A concept then, is an abstraction and achievement of the concept is demonstrated by the use of the abstraction for classification, communication and problem solving, according to the standard of the culture. In concept learning an individual can discriminate, describe characteristics, use words and apply the knowledge (Vaidya, 1997).

In case of human learning, concept formation is a valued goal. Throughout our instructional arrangement we intend to organize examples and situations in such a way that the learner will be able to acquire concepts. This process of concept formation or concept development involves an abstraction or a perceptual drawing out of the common elements in things and ideas. Generally we designate a concept by its name, such as tree, friendship, honesty, ugly, truthfulness etc. In all these concepts we find a reference to a category or classes of stimuli. Thus the term ‘tree’ does not refer to a specific ‘tree’ but a whole class of such things is known as ‘tree’.

The concepts can be analyzed in terms of two qualities: Class of stimuli represented by them and the common characteristics or attributes running through them. Johnson (1972) has described four varieties of concepts as under-

- Class Concept: In this variety knowledge is organized. In this context, class and category are synonyms. Classes are discrete structure that
differ quantitatively one from another. Most classes are multi-
dimensional, characterized by two or more attributes. Classes can be
defined (extensively), by identifying the instances included in them, and
(intensively) by describing the attributes of the class.

- Dimensional Concept: They have in common with class concept but
dimensions are continuous, while classes are discrete, as 'very bad',
and 'very small'.

- Explanatory/Principle Concepts: A principle is an abstraction of the
higher order of complexity than a concept since it states a relation
between concepts either dimensional, or class concept.

- Singular Concepts: A singular term refers to a single object or event.
As concept of the Moon or the concept of the Taj Mahal.

There are three types of concepts usually identified in an educational
context (Pandey, 1983) -

- Conjunctive Concepts – When the appropriate values of several
characteristics are jointly present, the concept is known as Conjunctive.
For example tree, dog etc.

- Disjunctive Concepts – When the characteristics and values are
substituted for one another, the concepts are called Disjunctive. For
example rules.

- Relational Concepts - When there is a specific relationship between the
characteristics the concept is called Relational. Carroll (1964) refers to
several relational concepts which are difficult to learn e.g. time, money,
many, few, average etc. Concepts are generally organized in a
hierarchy, with the most inclusive general concept at the top and the
more specific, less inclusive ones at the bottom (Gagne, 1970).

Concepts can be used in the process of education to help facilitate the
economy of efforts. They reduce the complexity of the environment, help us to
identify the objects of the world around us, minimize the necessity of constant
learning, provide directions for instrumental activity, and make instruction
possible. Without the development of proper concepts higher level learning
and teaching would not be possible to arrange. So learning of the concept
must be related to the learner's level of intellectual development (Dandapani, 2004).

A large proportion of science concepts of both basic and applied nature require students to operate at the formal operational level of intellectual development. But, a large majority of students do not use formal operational thinking when dealing with such concepts and problems. They exhibit large differences in their ability to grasp and understand science concepts. This mismatch between the levels of pupils thinking and intellectual demand of the subject matter is one of the major causes of learning difficulties in science (Prakash, 1990).

Concept learning is regarded as the identification of the concept attributes which can be generalized to newly encountered examples and discriminate examples from nonexamples (Vaidya, 1997). Learning of a concept is a broader term which includes most of the terms of conceptual learning. Learning a concept is a form of problem solving (Travers, 1977) because discovering the meaning of the concepts involves problem solving.

When reading scientific texts, students often try to rotely learn big words, facts and details instead of trying to understand ideas. They learn so that they can 'report back' information but not apply it (Roth, 1994). Many learners are impeded by the perceived difficulty of concepts presented to them and in the mode of presentation. So, student's conceptual structures are studied in all curricular areas in the hope of remediating such impediments to learning.

It is a well known fact that despite the best efforts made by teachers, students do not grasp fundamental ideas covered in the class. Even some of the students give the right responses but are only using correctly memorized words. When questioned more closely these students reveal their failure to understand fully the underlying concepts (Mestre, 1999). Hestene and Halloun(1995) and Eryilmaz and Surmeli (2002) revealed that some times students give correct answers but they do not have scientific conceptions to be termed as false positives. In contrast to it, some times students give incorrect answers but when questioned deeply these students reveal the correct scientific conceptions to be termed as false negatives/mistakes.
1.2.4 Errors

Barrass (1984) wrote of ‘mistakes’ or ‘errors’ and ‘misconceptions’ or ‘misleading ideas’ and is of the view that only teachers and brighter students can correct errors in learning of concepts. Lawrenz (1986) investigated in-service elementary school teacher’s understanding of some physical science concepts and found that some of the errors were due to lack of content knowledge but that others were indicative of serious misconceptions. Eryilmaz and Surmeli (2002), Haki (2005) and Kutuluay (2005) revealed that errors among secondary school students were due to mistakes, lack of knowledge and misconceptions. While identifying errors and misconceptions among students they referred mistakes as the incorrect answers given by the students who have correct scientific conceptions while lack of knowledge as the incorrect answers given by the students who have incorrect scientific conceptions and have no confidence for their wrong conceptions, in case the students have confidence for their wrong conceptions, these were referred as misconceptions. It may be stated that learning difficulties are responsible many a times for the errors committed by the students.

Kausathana and Tsaparlis (2002) classified errors into ‘systematic’ and ‘random’ errors.

- **Systematic Errors**: These errors are caused by learning difficulty or by difficulties or failures in understanding of the underlying theory, concepts or processes.

- **Random Errors**: These errors are caused not by lack of relevant knowledge or by a misconception, but by hastiness, or by thoughtfulness, or by an overload of working memory, or by field dependence. It may also be caused by a combination of the above factors.

There are specific patterns of test taking errors while measuring the learning outcomes. Paul (1998) has categorized error patterns in the following manner:

- Missing more questions in the 1st-third, 2nd-third or last-third of the test.
- Not completing a problem to its last step or not answering a question fully.
• Getting struck on one problem or question and spending too much time.
• Changing test answers from the correct ones to incorrect ones.
• Rushing through the easiest part of the test and making careless errors.
• Miscopying an answer from the scratch work to the test copy.

Error is the state of departing from truth (21st Century Dictionary, 2004).

It may be pointed out that students make many types of errors in tests but all errors are not misconceptions, some errors may be due to objectively false conceptions (when the student gives incorrect answer and incorrect reason for a particular concept) which may produce misconception (Wikipedia, The Free Encyclopedia, 2008) and therefore, it is important to identify the errors patterns on one hand and misconceptions on the other hand so that learning takes place in a correct and holistic manner.

1.2.5 Misconceptions

"Between the thought and the word spoken, between the word spoken and the word heard, between the word heard and the meaning taken, lies a vast gulf"

(Dunlop, 1997).

Children come to school already holding beliefs about how things happen, and have expectations - based on past experiences - which enable them to predict future events. They also possess clear meanings for the words which are used both in everyday language and in a more specialized way in science. A child's view and understanding of the word meanings are incorporated into conceptual structures which provide a sensible and coherent understanding of the world from the child's point of view (Osborne and Gilbert, 1980).

Science educators who were interested in conceptual development have used a variety of terms to describe the situation in which students' ideas differ from those of scientists about a concept, like student's misconceptions, naïve theories, alternative conceptions and alternative frameworks (Blosser, 1987).

Students do not come to the classroom as "blank slates" (Resnick, 1983). Instead, they come with the theories constructed from their everyday
experiences. They have actively constructed these theories and use these to make sense of the world are, however, incomplete half truths (Mestre, 1987). These are misconceptions. Misconceptions are any unfounded belief that does not embody the element of fear, good luck, faith or supernatural intervention. These misconceptions are given several names including “alternative frameworks” (Driver and Easley, 1978), ‘children’s science’ (Osborne, and Cosgrove, 1983), and ‘misconceptions’ (Griffiths and Preston, 1992). Further it has been reported in a number of researches that repeating a lesson or making it clearer will not help students to overcome misconceptions (Champagne, Klopfer and Gunstone, 1982; McDermott 1984; and Resnick, 1983). Rather students who even overcome misconceptions after ordinary instructions often return to misconceive only a short time later.

Students of all ages come to school with private theories about how the world works. But it is not just kids who have these misconceptions (Black, 2006). Gardner (1991) says many highly educated adults rely on the “models, beliefs, and theories” they developed as preschoolers. Very young children acquire theories through sensory-motor experiences, such as riding a bike or bouncing a ball. By the age of 5 or 6, "Children have a robust and serviceable set of theories about mind, matter, life and self".

It is argued that misconceptions serve the needs of the persons who hold them (Blosser, 1987). These erroneous ideas may come from strong word association, confusion, conflict or lack of knowledge (Fisher, 1985). Ausubel (1968) commented on the importance of pre-conceptions in the process of learning and said that the unlearning of preconceptions might well prove to be the most determinative single factor in the acquisition and retention of the subject-matter knowledge. So much research has focused on establishing the nature of student’s alternative conceptions in the hope to remediating the impediments to learning (McCloughlin and Mathews, 2002). Accordingly some alternative conceptions judged to be erroneous ideas or misconceptions have certain characteristics in common that are:

- They are at variance with conceptions held by experts in the field.
- A single misconception or a small number of misconceptions tend to be pervasive (shared by many different individuals).
Many misconceptions are highly resistant to change or alteration at least by traditional teaching methods.

Misconceptions some times involve alternative belief systems comprised of logically linked sets of propositions that are used by students in systematic ways.

Some misconceptions have historical precedence; that is some erroneous ideas put forth by students' today mirror ideas espoused by early leaders in the field.

Misconceptions are a problem for two reasons. First, they interfere with learning when students use them to interpret new experiences. Second, students are emotionally and intellectually attached to their misconceptions, because they have actively constructed them. Hence, students give up their misconceptions, which can have such a harmful effect on learning, only with great reluctant (Mestre, 1999). Misconceptions can be categorized (Dykstra, 1995):

- **Preconceived notions** are the popular conceptions rooted in everyday experiences.
- **Conceptual misunderstandings** arise when students are taught scientific information in a way that does not provoke them to confront a preconceived notions and non scientific beliefs.
- **Non scientific beliefs** include views learned by students from sources other than scientific education such as religious and mythical teachings.
- **Vernacular misconceptions** arise from the use of the words that mean one thing in everyday life and another in a scientific context.
- **Factual misconceptions** are the falsities often learned at an early age and retained unchallenged into adulthood.

Hershey (2004) has classified misconceptions in five categories i.e. oversimplification, overgeneralization, obsolete concepts and terms, misidentifications and flawed research. It has been observed by the researcher that some misconceptions are easier to identify because they are oversimplification, overgeneralization or misidentifications. Others are more difficult to identify because they are obsolete concepts and terms or flawed research.
In Piaget's view, misconceptions add on each other like a structure. Misconceptions start as a gap resulting from the lack of knowledge. This gap fills incidentally with the quality education given by the teacher, the present knowledge of the students and the experiences that they face. The knowledge obtained in this way fills the gap successfully to some extent, but after a certain point it may come as misconception.

Significant learning requires integrating new ideas with existing knowledge. Sometimes this old knowledge - new knowledge connection is successful, but sometimes it leads to errors in understanding or misconceptions (West and Pines 1985). When students combine new information with previous learning, Misconceptions may arise from two sources:

- from errors in understanding new information or
- from previous misunderstanding remaining a part of the newly formed knowledge (Debra, 1993).

1.2.6 Measurement of Errors and Misconceptions

The researches seem to show that the first step in diffusing errors and misconceptions is to detect them by assessing their prior knowledge through informal quizzes, flow charts, concept maps and discussions that encourage students' freedom of expression (Debra, 2000). General achievement test attempts to assess students' performance in school subjects in terms of single score and the test does not identify specific errors and weaknesses etc. The diagnostic achievement tests, on the other hand, intend to discover specific deficiencies in learning. The multi-tier concept achievement test has the ability to assess students' performance in the subject, errors committed by students in the test (wrong answers in the first tier) and to differentiate misconceptions from lack of knowledge as the sources of errors.

Researchers have developed diagnostic tests for measuring students' understanding of conceptions for a long time. The most commonly used diagnostic tests can be listed as interviews and multiple choice tests. Each tool is selected for some advantages. Interviews have the advantage over multiple choice tests in terms of flexibility and depth of the investigation (Osborne and Gilbert, 1980; Beichner, 1994). However, interviews can be conducted with a limited number of students for generalization and they
consume plenty of time. On the other hand, multiple choice tests can be administered to a large number of students at a time for generalization and responses can easily be analyzed although they can not investigate the students' responses deeply and can detect only the most frequently appearing errors (Rollnick and Mahooana, 1999). Therefore, Beichner (1994) argued that the ideal course of action is to use both of these diagnostic tools in the multiple choice test development process for minimizing the disadvantages of each tool. In fact before Beichner (1994) emphasized, interviews had already been conducted in the process of developing a multiple choice test. Mechanics Diagnostic Test was developed by Halloun and Hestenes (1985), purely on the basis of interviews to identify errors and misconceptions.

Another type of diagnostic tool is the two-tier test which was developed by Treagust (1988, cited in Tan, Goh, Chia and Treagust, 2002). In a two-tier test, the first tier presents a multiple choice content question and the second tier presents a set of reasons for the given answer in the first tier. In the design of this type of diagnostic tool, interviews were also conducted to form a list of misconceptions, which are used as distracters in the second tier. Several two-tier diagnostic tests have been developed and are described in literature (Haslam and Treagust, 1987; Odom and Barrow, 1995; Tan and Treagust, 1999; Tan et al., 2002; Treagust, 2006). Nonetheless, Griffard and Wandersee (2001) used a two-tier test that had been developed by Haslam and Treagust (1987) in their study and criticized it. They claimed that the instrument items actually diagnose isolated errors in a conceptual framework rather than the robust naive theories because the test items were based on scientifically correct propositions from the concept map which had been used in the design of the test, that is, the participants were not allowed to give their reasons in the test. The researchers also emphasized that the test results overestimate the percentage of misconceptions because gap in knowledge (lack of knowledge) can not be distinguished from misconceptions and argued for a three tier test to objectively identify errors and misconceptions.

Eryilmaz and Surmeli (2002) developed a three-tier test, the third tier seeking level of confidence of students to assess students' misconceptions concerning heat and temperature. As a result of the study, it can be said that three-tier tests have the advantage over the two-tier tests in discriminating
lack of knowledge from their misconceptions by means of third tier items which assess how confident the students are about their responses for the first and second tiers. Some three-tier tests have been described in the literature (Griffard and Wandersee, 2001; Eryilmaz and Surmeli, 2002; Haki, 2005; Kutluay, 2005; Kukukozar and Kocakulah, 2007). This test consists of test items to be responded on three tiers. First tier includes multiple choice items and required students to select correct answer. Each question had one correct answer and three distracters. Second tier required students to write reason of the response. While third tier asked students about their confidence for the answer of former two tiers. Total achievement score of each student was calculated according to the students' multiple choice item scores, reasoning part scores and the confidence level scores together. The scoring pattern in these tests was as under:

**Correct Answers:** The number and percentage of the correct answers to the first tier for each item and total correct answers of the students for the first tier of test were calculated.

**True Conceptions:** The number and percentage of the correct answers to the first two tires (if student has given correct answer in first tier and correct reason in second tier) for each item and total correct answers of the students for the first two tires of the test were calculated.

**Complete Understanding of Concept:** It is important to say that even if a student's answers for the first two tires were correct, it was not accepted unless the students clarified his/her confidence in the third tier. If the students said, "Yes, I am sure" it was accepted true and if the student said, "No, I am not sure" it was accepted false. The percentage of the correct answer to the all three tiers for each item and total correct answers of the students for all the three tires were calculated.

In this type of the test the proportion of right answers decreases as the tier of the test increases. The difference (decrease) in the proportion of the correct answers in one tier (correct answers) and two-tier test (true conceptions) gives false positives (the correct answers given by students who do not have scientific conception) and the difference (decrease) in the proportion of the correct answers in two tier- test (true conceptions) and three-tier test (complete understanding of concept) attributes to lack of knowledge.
because the right answers can not be accepted unless the student shows his confidence in the third tier.

**Error:** The percentage of the wrong answers to first tier was estimated and also the number of errors for each student for first tier was calculated.

**Objectively False Conceptions:** The percentage of the wrong answers according to first two tiers (if student has given wrong answer in first tier and wrong reason in second tier) were estimated and also the number of the wrong answers for each student for first two tiers were calculated.

**Misconceptions:** It is important to say that even if a students' choice selection for the first two tiers indicated wrong answer it was not accepted as a misconception unless the students clarified his/her confidence in the third tier. The percentage of the misconceptions according to the all the three tires was estimated and the number of misconceptions for each questions for all the three tires was calculated.

In this type of the test the percentage of students having wrong answers decreased as the tier of the test was increased. The difference (decrease) in the percentage of the students having wrong answers according to one tier test (errors) and two-tier test (objectively false conceptions) was due to false negatives (the percentage of students who gave wrong answers to the first tier of any item and correct reason to the second tier of that item). The percentage of false negatives should be less than 10% (Hestene and Halloun, 1995), because each item has many distracters and since the test was a misconception test, the items of the test had powerful distracters. So, the students might have fallen in inconsistency (mistake) due to powerful distracters.

Similarly, the percentage of wrong answers decreased as the tier of the test increased from two-tier to three-tier test. The difference (decrease) in the percentage of students having wrong answers according to two-tiers (objectively false conceptions)and three-tier test (misconceptions) was due to lack of knowledge.

Therefore, it can be stated that after the identification of errors and prior to the identification of misconceptions: mistakes, objectively false concepts and lack of knowledge may emerge in between.
1.3 STATEMENT OF THE PROBLEM

It may also be pointed out that there is much stress of researches in the area of science achievement and problems encountered by the students in the form of committing errors and misconceiving the science concepts. However there is paucity of researches in the area "errors and misconceptions in learning of scientific concepts" in Indian context. Hence the present study is an endeavor in this direction to provide empirical evidence with regard to problems in learning of scientific concepts with objectivity and scientifically. This study will contribute to filling the gap in the literature. In other words, deficiency of one tier and two-tier tests make this type of studies a necessity due to superiority of three tier tests.

In the light of ongoing researches in science teaching and learning and emerging needs of teaching science with scientific approach, the research problem is being undertaken as stated below:

A STUDY OF ERRORS AND MISCONCEPTIONS IN SCIENCE AT SECONDARY SCHOOL STAGE

1.4 SIGNIFICANCE OF THE STUDY

Science education has been given utmost importance in educational programmes to equip the young learners with skills that will enable them to be rational, progressive and forward looking citizens of the nation in the era of science and technology. Still there is more emphasis on the rote learning and the learning with understanding has been neglected in the existing curricular transaction process. Hence the findings of the study are expected to provide an insight into learning of scientific concepts in a scientific method by identifying errors and misconceptions in science learning and enhance the probability of better achievement.

Today our global environment is being stressed by many different factors, including habitat destruction, pollution, and invasion of non-native species, global warming and depletion of ozone layer. This study will help the students as well as teachers to understand about the complex relationships that drive our natural ecosystems and the degree to which humans depend
upon these ecosystems for their very survival, and make them better prepared for making environmentally sound decisions in their life time.

Also the methodology adopted in the identification of errors and misconceptions will provide a lead to future researchers, not only in the area of science, but other subjects as well, therefore, it is expected that the results of the present study will open new vistas for researchers to provide new direction in teaching – learning process along with providing some concrete suggestions for educational practitioners to adopt such strategies in school education. Moreover, the findings of the study will have an implication for teacher education programmes, both pre-service and in-service, to train teachers to adopt such strategies in evaluation of learning outcomes and help students to perform with excellence.

1.5 OBJECTIVES OF THE STUDY

- To construct and standardize Concept Achievement Test (CAT) in science for secondary school students.
- To find out the level of performance of secondary school students on Concept Achievement Test (CAT) in science.
- To find out the percentage of secondary school students who committed errors on Concept Achievement Test (CAT) in science.
- To identify the sources of errors and misconceptions and determine the percentage of secondary school students in different types of errors and misconceptions on Concept Achievement Test (CAT) in science.
- To study the patterns of errors and misconceptions on Concept Achievement Test (CAT) in science in relation to gender.
- To study the patterns of errors and misconceptions on Concept Achievement Test (CAT) in science among secondary school students in relation to location.
- To study the patterns of errors and misconceptions in Concept Achievement Test (CAT) in science among secondary school students in relation to academic achievement.
- To study the patterns of errors and misconceptions on Concept Achievement Test (CAT) in science in relation to scientific attitude.
1.6 DELIMITATIONS OF THE STUDY
The present research study was delimited in the following manner:

- Only Government secondary schools of Punjab, affiliated to PSEB constituted the universe for the study.
- The Concept Achievement Test (CAT) in science was delimited to the unit of environment of science text book prescribed for 9th class students.
- Only conceptual issues were taken up for construction of Concept Achievement Test (CAT) in science.
- The numerical aspect of any kind of concept was not included in the study.
- The identification of errors and misconceptions, as per students' performance on Concept Achievement Test (CAT) in science was determined through descriptive method and no remedial instruction will be provided to students.

1.7 OPERATIONAL DEFINITION OF TERMS
The key terms used in the study may be operationally defined as under:

- **Error**: Error is the state of departing from truth or it is the state of being inaccurate (wrong) in behaviour (21st Century Dictionary, 2004), taken as wrong answers given to the multiple choice test items (first tier) of Concept Achievement Test (CAT) in science because multiple choice test is the most frequently used tool for detecting most frequently appearing errors (Rollnick and Mahooana, 1999). Students make many types of errors in tests but all errors are not misconceptions some errors may be objectively false conceptions. Errors may be due to mistakes, lack of knowledge and misconceptions among students (Eryilmaz and Surmelı, 2002; Haki, 2005; and Kutuluay, 2005).

- **Objectively False Conceptions**: The objectively false conception is the gap between the errors and misconceptions, taken as incorrect answer in first tier (error) and incorrect reason in second tier of
Concept Achievement Test (CAT) in science. Objectively false conceptions may produce misconceptions (Wikipedia, The Free Encyclopedia, 2008). In conveying a concept the students having objectively false conceptions may give the incorrect answers due to lack of knowledge or due to misconceptions.

- **Misconceptions:** These refer to intuitive ideas that students have constructed for themselves as a result of experiences with their physical environment, popularly known as students' conceptions, children's science alternative conceptions or alternative frame works (Gilbert and Watts, 1983), and as private concepts, naïve theories and half truths (Mestre, 1987) and as naive conceptions or naive knowledge (Reiner, Slotta, Chi and Resnick, 2000) and as commonsense beliefs (Hestenes, Wells and Swackmer, 1992). All the errors are not misconceptions, since misconceptions happen when a person shows confidence in the objectively false concept (Wikipedia, The Free Dictionary, 2008) and can be assessed in Concept Achievement Test (CAT) in science by referring to incorrect answer in first tier, incorrect reasoning in second tier and confidence shown by the student in third tier.