CHAPTER I
THEORETICAL BACKGROUND OF THE STUDY

Contents

1.1 Nature of science and science teaching 1

1.2 Constructivism and science teaching 11
  1.2.1 Faces of constructivism 13
  1.2.2 Constructivism - its theory and models 20
  1.2.3 Role of constructivist approach in science classroom 26
  1.2.4 Role of teacher in a constructivist classroom 34

1.3 Rationale and significance of the present study 35

1.4 Statement of the problem 40

1.5 Operational definitions of the terms used 41

1.6 Variables included in the study 44

1.7 Objectives of the study 44

1.8 Hypotheses formulated for the study 45
CHAPTER I

THEORETICAL BACKGROUND OF THE STUDY

This chapter discusses the nature of science and science teaching in the context of constructivism. The theory, models and approaches of constructivism are presented. Then the rationale and significance of the study followed by the statement of the problem, objectives of the study and hypotheses of the study are also presented.

1.1 Nature of science and science teaching

Science as an enterprise has individual, social, and institutional dimensions. It is fundamentally a means of understanding why things happen as they do. Man has found science as a process by which his search for answers to his unlimited questions can be approached systematically. In this way the study of science is an intellectual and social endeavor-the application of human intelligence in figuring out how the world works-should have a prominent place in any curriculum that has science literacy as one of its aims.

Bullock (1976), a historian has deemed science to be 'the greatest intellectual and cultural achievement of modern man'. He perceived science as an open-ended process in which imagination, hypothesis, criticism and controversy take a dominant role. It is not, nor was it ever, 'the closed dogmatic system of immutable laws beloved of 19th century positivists'. Bullock sees science as a humane activity, deeply concerned with man and society, providing scope for imagination and compassion as well as for observation and analysis.
Conant (1951), an eminent scientist and an educator also 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 thus, 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 scientific attitudes and methods of inquiry - which is the 'process' of science. Science thus is a combination of both 'processes' and 'products' related to and dependent upon each other. When, used in this way, science offers methods of inquiry useful in learning more about the universe and its workings. The interrelation and expanding nature of the processes and products of science is shown in the following figure.
The processes of science include scientific attitudes and methods of inquiry. Scientific attitudes include both emotional attitudes such as curiosity, humility, determination and open mindedness; and intellectual attitudes namely objectivity, skepticism and rationality. The methods of inquiry are observing, hypothesizing, analyzing, inferring, extrapolating, reasoning, synthesizing etc. The scientific attitudes develop simultaneously with science process skill development and with the discovery or construction of useful science ideas. The information and ideas of science that compose its knowledge base are often referred to as 'products' since new discoveries add to the base of scientific information which are the products of curiosity and experimentation. An interesting thing about science knowledge is that new discoveries often lead to more questions, more experiments, and further
discoveries. The science cycle move under its own momentum, propelled initially and again later sustained by human curiosity and a desire to explain natural phenomena. The effect is an exploding accumulation of new information that is added to the knowledge base. Scientific knowledge consists of primarily facts, concepts, principles and theories. The scientific theories are refined in the light of new ideas which Kuhn (1970) called a new paradigm.

It is a well known fact that children are curious. Their curiosity motivates them to discover new ways to use this powerful key for unlocking the mysteries of their world. As said earlier both the products and processes for acquiring them are to be experienced by the students. Children receive a whole science experience when they are immersed in all the three parts of science. The synergy among the parts which makes science whole is shown in the Science cycle given in figure 1.2.

Figure 1.2 The Science cycle
Attitudes are mental predispositions towards people, objects, events and so on. In science, attitudes are important because of three primary factors. First, a child's attitude carries a mental state of readiness with it. With a positive attitude the child will perceive science objects, topics, activities and people positively. Secondly, attitudes are not innate or inborn. They are learned and organized through experiences as children develop. Thirdly, attitudes are dynamic result of experiences that act as directive factors when a child enters into new experiences. As a result attitudes carry an emotional and an intellectual tone. Attitudes not only improve achievement, they also build up interest and self esteem which is represented in the following diagram.

**Figure 1.3 Importance of basic science attitudes**

**Source:** Adapted from Benjamin Bloom, *Human characteristics and school learning* (New York: McGraw-Hill, 1979)

It is essential to distinguish between the two broad subsets of science related attitudes. Attitude towards science according to Duckworth (1975) refers to the "disposition of mind for or against scientists, scientific activity and learning of
science" and has predominantly affective orientation. On the other hand scientific attitude is "the cognitive attitude or belief about thinking and has also affective and behavioral aspects" (Guilford, 1967). Grinell had listed down around 20 scientific attitudes namely; empiricism, determinism, a belief that problems have solutions, parsimony, scientific manipulation, skepticism, precision, respect for paradigm, a respect for power of theoretical structure, willingness to change opinion, loyalty to reality, aversion to superstition and an automatic preference for scientific explanation, a thirst for knowledge, an "intellectual drive", suspended judgment, awareness of assumptions, ability to separate fundamental concepts from the irrelevant or unimportant, respect for quantification and appreciation of mathematics, an appreciation of probability and statistics, an understanding that knowledge has tolerance limit and empathy for the human condition.

Apart from the knowledge and attitudes, there is one more part of science i.e. science process skills. Children learn how to learn by thinking critically and using information creatively. They continue to learn how to learn when making discriminating observations, when organizing and analysing facts and concepts, when giving reasons for expected outcomes, when evaluating and interpreting the results of experiments and when drawing justifiable conclusions (Victor, 1985). In science, the ways of thinking, measuring, solving problems and using thoughts are called processes. Process skills describe the type of thinking and reasoning required.

Science process skills may be divided into two types: basic and integrated skills. Basic skills include observing, classifying, communicating, measuring,
estimating, reasoning, predicting and inferring. Integrated skills include identifying, controlling variables, defining operationally, hypothesizing, experimenting, graphing, interpreting, modelling and investigating.

Science process skills along with science related attitudes lead to discovery, of scientific knowledge that is the product side of science. Scientific knowledge is tentative. A scientific finding or a prediction, which is accepted to be true at a particular time, is probabilistic and not absolute. It is derived from imagination, observation and experimentation. Scientific knowledge is rational and empirical i.e. it has its origin in the real world, and dependent on sense experiences. It is holistic; the knowledge gathered by various branches of science contribute to an overall conceptual scheme or mental construct, which is internally consistent. As a product of creative human imagination, concepts of science reflect the social and cultural background of their times.

The values that underlie science represent the very human origin itself. It can be argued that without these values, the enterprise of science could not have occurred. They are,

- Consideration of consequences - decision based on the assessment of the effects emanating from an action or a set of actions.
- Longing to know and understand.
- Demand for verification - search for supporting evidence to verify the validity and accuracy of a statement.
• Questioning - belief that all things, including "self-evident" truths are open to question.

• Respect for logic - consideration of influences that emerge from cause-effect relationships.

• Search for data and their meanings.

Why teach science in school? or more importantly - Why should young people at school attempt to learn it? There are a number of responses to these questions. Association for Science Education (ASE, 1981) gave explanations to these questions, as science is both deeply interesting and beautiful in construction. The pursuit of knowledge in science is an end in itself, an intellectual activity leading to the creation of further research and knowledge. Science is a part of the world of ideas; its history, philosophy, literature, pedagogy and social institutions contribute to the culture of our societies. Science has high utilitarian value. High achievement in science can lead to a wide range of life chances, active participation in the process of democratic decision making, understanding how some principles and laws in science can provide a basis for rational choice in life contexts.

Learning of science in schools augment the spirit of enquiry, creativity and objectivity along with aesthetic sensibility. It aims to develop well-defined abilities of knowing, doing and being. It also nurtures the ability to explore and seek solution of the problems related to the environment and daily life situations and to question the existing beliefs, prejudices and practices in society. Thus science is must for every child to learn as it gives an opportunity to learn how to learn. In India the
inclusion of science as a discipline and improvement in the science education is
the successful effort of various committees and commissions.

One of the oldest commissions, University Education Commission (1948) felt
that improvement of curriculum and syllabus at the secondary level is essential for
the improvement of University Education and recommended the inclusion of science
as a discipline at secondary level. Later Secondary Education Commission (1953)
suggested compulsory inclusion of general science and mathematics as core
subjects at the middle school as well as secondary level. Then the Indian Education
Commission (1964-66) identified the need of a revolution in the educational system
through internal transformation by relating it to the life needs and aspirations of the
nation, by achieving qualitative improvement, by expanding educational facilities
and by relating education to productivity and recommended science as an integral
part of education. Science teaching was 'to promote an ever deepening
understanding of basic principles; to develop problem solving and analytical skills;
and to inculcate ability to apply them to the problems of the natural environment
and social living and to promote the spirit of inquiry and experimentation'. Overall it
heralded a major shift in the school science policy from a general science approach
to structure of discipline approach.

During the period 1967-72, efforts were mounted to implement the
recommendations of UNESCO Planning commission (1964) and Education
Commission (1964-66). Besides this The Planning Group Education (1968) gave
high priority to the development of science education by laying emphasis on the
development of scientific attitudes and skills. In 1972 a variety of materials such as Physical Science Study Committee (PSSC), Biological Science Study Committee (BSSC), School Mathematics Study Group (SMSG) and Chemical Bond Approach (CBA) etc were produced. Again the period 1972-77 was a watershed for the school science education policy in our country. Entirely new approaches of teaching science emerged in schools.

Considerable effort was made at national level by NCERT (1961) to improve the quality of science education. Revision of the science curriculum, providing in-service training for science teachers on the new approaches of teaching and evaluation were the major focused areas. According to the 42nd amendment of the Constitution of India - Part IVA fundamental duties of citizen 51A(h), it shall be the duty of every citizen of India to develop the scientific temper, humanism and the spirit of enquiry and reform (1976).

Based on the recommendations given by the above committees and commissions the following main objectives of science teaching were arrived for secondary schools.

The teaching of science at secondary level should aim at acquisition of

- knowledge of fundamental principles and concepts useful in daily life.
- skills of experimentation, construction, observation, drawing and problem solving and invention.
abilities in the students such as ability to sense a problem; to organize, interpret, analyse, generalize, predict from given data, organize science exhibition, fairs etc.

inculcating interest in the environment they live in.

scientific attitudes like critical thinking, open-mindedness, curiosity, objectivity, free from superstitions and false beliefs, willingness to suspend judgments, belief in cause and effect relationship, rationality etc and interests.

a broad genuine appreciation of what development of science means to modern, social, industrial and national life and preparing the students for better living i.e forming basis for vocational career.

train the students for reflective thinking

1.2 Constructivism and science teaching

Tracing the schools of learning, one would see how there had been a different gamut of ideas and origin of developmental schools resulted in behaviorism and cognitivism. Behaviorism, which associates learning to response strengthening, whereby the learner is repeatedly cued to give a simple response followed by immediate feedback and passively receives rewards and punishment, is simply becoming irrelevant. Cognitivism associates learning to knowledge acquisition and considers information as a commodity that can be transmitted directly from teacher to learner may retain some relevance but is not enough. This is constructivist
 Constructivism associates learning to the building of one's own knowledge, is much more appropriate to today's situation, in that it views learning in the perspective of the learner. The teacher is considered as a cognitive guide while the learner is empowered to construct his own meaning, not just memorize the right answers.

Constructivism is not a new concept. It is a learning or meaning making theory. It suggests that individuals create their own understandings, based upon the interaction of what they already know and believe and the phenomena or ideas with which they come into contact. Constructivism is a descriptive theory of learning not a prescriptive theory of learning. It has its roots in philosophy and has been applied to sociology and anthropology, as well as cognitive psychology and education. Perhaps the first constructivist philosopher, Giambatista Vico commented in a treatise in 1710 that "one only knows something if one can explain it" (Yager, 1991). Constructivism is a theory of how the learner constructs knowledge from experience, which is unique to each individual. Duckworth (1987) defined constructivism succinctly: "Meaning is not given to us in our encounters, but it is given by us, constructed by us, each in our own way, according to how our understanding is currently organized".

Crowther (1997), defined constructivism as "Basically defined, constructivism means that as we experience something new we internalize it through our past experiences or knowledge constructs we have previously established." Constructivism bristles with philosophical questions: it explicitly assumes positions in the philosophy of science, the philosophy of mind, and the philosophy of education. It is at once a theory of science, of human learning and of teaching.
Constructivism according to Piaget (1971) is a system of explanations of how learners, as individuals adapt and refine knowledge. In this view learners actively restructure knowledge in highly individualized ways, basing fluid intellectual configurations on existing knowledge, formal instructional experiences.

Most constructivists would agree that the traditional approach to teaching - the transmission model - promotes neither the interaction between prior and new knowledge nor the conversations that are necessary for internalization and deep understanding. The information required from traditional teaching if acquired at all, is usually not integrated with other knowledge held by the students. Thus new knowledge is often only brought forth for school-like activities such as examinations and ignored as all other times.

Among the constructivists, there are those who focus on the individual acting as sole agent in the process of constructing and reconstructing meaning. Others focus on the socio-cultural context in which an individual lives and still others on both the individual and social by suggesting that it is not useful to separate the two analytically.

1.2.1 Faces of constructivism

The various faces of constructivism are as follows:

i) Trivial constructivism

This is the simplest idea in constructivism what Glaserfeld (1990) calls trivial constructivism also known as personal constructivism. The principle has been
credited to Piaget, pioneer of constructivist thought, and can be summed up by the following statement:

"Knowledge is, actively constructed by the learner, not passively received from the environment". This reacts against other epistemologies promoting simplistic model of communication as simple transmission of meanings from one person to another. The prior knowledge of the learner is essential to be able to "actively" construct new knowledge.

ii) Radical constructivism

It adds a second principle to trivial constructivism, which can be expressed as; "Coming to know is a process of dynamic adaptation towards viable interpretations of experience. The knower does not necessarily construct knowledge of a "real" world".

Radical constructivism challenges the notion of external reality; no amount of stimuli, experience, or thinking is sufficient to prove the existence of an external agent. Radical constructivism does not deny an objective reality but simply states that we have no way of knowing what that reality might be. Mental constructs, constructed from past experience help to impose order on one's flow of continuing experience. However, when they fail to work, because of external or internal constraints, thus causing problem, the constructs change to try and accommodate the new experience. Within the constraints that limit our construction there is room for infinity of alternatives. From a radical constructivist perspective, communication
need not involve identically shared meaning between participants. It is sufficient for their meanings to be compatible (Hardy and Taylor, 1997). The emphasis here is still clearly on the individual learner as a constructor. Neither trivial nor radical constructivism looks closely at the extent to which the human environment affects learning. These issues are focused on in more detail by social, cultural and critical constructivism.

iii) Social constructivism

The social world of a learner includes the people that directly affect that person, including teachers, friends, students, administrators and participants in all forms of activity. This takes into account the social nature of both the local processes in collaborative learning and in the discussion of wider social collaboration in a given subject, such as science.

Vygotsky (1978), a pioneering theorist in psychology focused on the roles that society play in the development of an individual. He believed everything is learned on two levels - first, through interaction with others and then integrated into the individual's mental structure. A more experienced partner is able to provide "scaffolding" of the subject matter to support the student's evolving understanding. Another aspect of Vygotsky's theory is the idea that the potential for cognitive development is limited to a "Zone of proximal development". This zone is the area of exploration for which the student is cognitively prepared but requires help and social interaction to fully develop. Cobb (1994) followed by Salomon and Perkins (1998) suggested that "acquisition" and "participation" the two metaphors of learning interrelate and interact in synergistic ways.
Teaching strategies using social constructivism as a referent include teaching in contexts that might be personally meaningful to students, negotiating taken-as-shared, meanings with students, class discussions, small-group collaboration, and valuing meaningful activity over correct answers (Wood et al, 1995).

iv) Cultural constructivism

Beyond the immediate social environment of a learning situation are the wider context of cultural influences, including custom, religion, biology, tools and language. For example the format of books can affect learning, by promoting views about the organization, accessibility and status of the information they contain.

"(What we need) is a new conception of the mind, not as an individual information processor, but as a biological, developing system that exists equally well within an individual brain and in the tools, artifacts, and symbolic systems used to facilitate social and cultural interaction." (Vosniadou, 1996).

The tools that we use affect the way we think (by tools including language and other symbolic systems as well as physical tools). Salomon and Perkins (1998) identified two effects of tools on the learning mind. Firstly, they redistribute the cognitive load between people and the tool while being used and secondly, the use of tool can affect the mind beyond actual use, by changing skills, perspectives and ways of representing the world. For example, computers carry an entire philosophy of knowledge construction, symbol manipulation, design and exploration, which if used in schools can subversively promote changes in curricula, assessment, and other changes in teaching and learning.
Higher mental functions are, by definition, culturally mediated. They involve not a direct action on the world but an indirect one; that takes a bit of material matter used previously and incorporates it as an aspect of action. In so far as that matter itself has been shaped by prior human practice, current action incorporated the mental work that produced in the particular form of that matter (Cole and Wertsch, 1996).

v) Critical constructivism

Critical constructivism looks at constructivism within a social and cultural environment, but adds a critical dimension aimed at reforming these environments in order to improve the success of constructivism applied as referent.

Taylor (1996) describes critical constructivism as a social epistemology that addresses the socio-cultural context of knowledge construction and serves as a referent for cultural reform. Critical constructivism adds a greater emphasis on actions for change of learning teacher. It is a framework using the critical theory of Habermas to help make potentially disempowering cultural myths more visible and hence more open to questions through conversation and critical self-reflection. An important part of that framework is the promotion of communicative ethics that is conditions for establishing dialogues oriented towards achieving mutual understanding (Taylor, 1998). The conditions include: a primary concern for maintaining empathetic, caring and trusting relationships; a commitment to dialogue that aims to achieve reciprocal understanding of goals, interests and standards; and concern for and critical awareness of the often-invisible rules of the classroom.
including social and cultural myths. Together these myths produce a culture that portrays classroom teaching and learning as "a journey through a pre-constructed landscape". Modification of such entrenched environments to reduce myths and promote approaches based on constructivism is problematic; because of the self-reinforcing mature of administration and the effects of wider culture.

**vi) Psychological constructivism**

Psychological constructivism is based on Jean Piaget's model of development of the individual. The process focuses learning as a personal, individual, intellectual construction based on experiences of one in the world. To Piaget, the child's mind is self-organized by a constant antagonism between internal, subjective mental states and external reality. In Piagetian theory there is no objective ontological reality. For Piaget (1952, 1969) the development of human intellect proceeds through adaptation and organization. Adaptation is a process of assimilation and accommodation, where, on one hand, external events are assimilated into thoughts and on the other; new and unusual mental structures are accommodated into the mental environment. The process of organization refers to the structuring of the adapted mental material. Piaget considers that the organization of the mind is accomplished through a series of increasingly complex and integrated ways, of which the simplest one is scheme, i.e. a mental representation of some action that can be performed on an object. As Piaget identifies knowledge with action, he considers that mental development organizes these schemes in more complex and integrated ways to produce the adult mind. This progression occurs because of the reciprocal effects of assimilation and accommodation constantly forced to attain equilibrium between subjective and objective states.
Piaget assumed that there exists four major periods of development in the evolution of human mind: The sensorimotor period (from birth to two) where in the child explores the world through action. This period is subdivided into pre-conceptual and the intuitive period. The pre-conceptual child (age 2 to 4) does not have fully developed concepts and the ability to abstract and discriminate relevant features. The child cannot appropriately use inductive and deductive ways of thinking. The intuitive child (age 4 to 7) forms ideas just from impressions and the child cannot consider more than one variable at once. In the concrete operational period (age 7 to 11), the child can manipulate numbers, develop concept formation skills and think hypothetically about coordinated action, where two or more variables can be considered at once. In the formal operational period (adolescence and adulthood), the child will have the capacity of abstract reasoning.
Learning by doing and forming ideas from exploration is the underlying theory behind psychological constructivism. The child is viewed like a scientist who possesses insights, questions, problem solving strategies and new ideas that will be used in experimentation. The scientific process of puzzling, probing, testing are incorporated into the approach. The child develops his picture or understanding of the physical world through manipulation and seeing relationships between objects and learning centrally determined names and labels for the ideas, items and activities involved through experience. Key to the theory is fostering independence in the child, not dependence on adults so that activities, curriculum, environment are based on risk-taking, self-direction, guided or totally free discovery type experimentation through social interaction and problem solving. The teacher acts as a facilitator of the educational context. The teacher provides opportunities for observation, interaction of students with each other and with the teacher through questioning techniques, modifying the environment, and support during conflicts and planning and creating curriculum.

1.2.2 Constructivism - its theory and models

Constructivism is anchored on cognitive psychology but from a practical perspective has roots in the "progressive" model of John Dewey (1933). According to this theory, learners are active participants in knowledge acquisition and engage in restructuring, manipulating, reinventing, and experimenting with knowledge to make it meaningful, organized and permanent. Learning is an internal process influenced by the learner's personality, prior knowledge and learning goals (Davidson, 1995).
Constructivism describes a learner-centered environment where knowledge and the making of knowledge is interactive, inductive and collaborative, where multiple perspectives are represented, and where questions are valued (Brooks and Brooks, 1993; Brown, Collins and Duguid, 1989; Lebow, 1993) and the importance of context related to knowledge and learning is emphasized. That is knowing and the process of learning are affected by the context of the learning environment and are referred to as "situated cognition" (Brown, Collins and Duguid, 1989). In addition, within the constructivist environment the importance of "authentic activity" (Brown, et al; Lebow, 1993) is emphasized as a part of the learning process.

Lerman, (1989) following Kilpatrick, (1987) suggested that the core epistemological theses of constructivism are

'Knowledge is actively constructed by the cognizing subject, not passively received from the environment'. 'Coming to know is an adaptive process that organizes one's experiential world; it does not discover an independent, pre existing world outside the mind of the knower'.

First point is a psychological claim and the second the epistemological claim. Wheatley (1991) offers a nearly identical summation of the epistemological core of constructivism. He said

"The theory of constructivism rests on the two main principles….principle one states that knowledge is not passively received, but is actively built up by the cognizing subject…. Principle two states that the function of cognition is adaptive
and serves the organization of the experiential world not the discovery of ontological reality.... Thus we do not find truth but construct viable explanations of our experiences."

Scott (1987) defines a constructivist in science as one who "perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use, make sense of everyday experiences. ..... Such a process is one in which learners actively make sense of the world by constructing meaning."

For Piaget, action rather than language is the basis of all knowledge. His theory describes the gradual evolution of thought in logical terms from stage to stage, which are also hierarchically determined. Vygotsky goes a step further saying "Instruction precedes development". He, therefore, analysed intellectual development as a function of instruction. Concepts do not exist in isolation. Vygotsky had a firm belief i.e. belief in the social construction of the mind. Within the context of cultural development, any function in the child appears twice namely social plane and psychological plane. The language plays the mediating role and Vygotsky thus, talked of the tools of language. He had a bold conception in the "Zone of proximal development" whereby individual activity is detached from communal practice. Jerome Bruner (1966) unlike Piaget believed in symbolic growth. He informed about what ought to be the plan of attack unlike Piaget who talked of the universal child. Bruner stressed the role of language and culture in education of children so that the children learn "how to learn". Along with Piaget and Bruner, Ausubel (1978)
was also a strong advocate of meaningful learner. He saw the importance of
meaning as a key factor for learning.

From the above theories, constructivists have evolved the following models
and approaches.

There are several constructivist design models available.

i) The learning cycle is a three-step design that can be used as a general
framework for many kinds of constructivist activities. The process begins with
the "discovery" phase. In it, the teacher encourages students to generate
questions and hypotheses from working with various materials. Next, the
teacher provides "concept introduction" lessons. Here the teacher focuses
on the students' questions and helps them create hypotheses and design
experiments. In the third step, "concept application" students work on new
problems that reconsider the concepts studied in the first two steps. The cycle
continues again.

ii) The Biological Science Curriculum Study (BSCS) developed an instructional
model for constructivism which was called the "Five Es" by Roger Bybee. In
these models the process is explained by employing five "E"s. They are:
Engage, Explore, Explain, Elaborate and Evaluate.

iii) Gagnon and Collay developed another constructivist learning design. In this
model, teachers implement number of steps in their teaching structure. They
develop a situation for students to explain; select a process for groupings of
materials and students; build a bridge between what students already know and what teachers want them to learn; anticipate questions to ask and answer without giving away an explanation; encourage students to exhibit a record of their thinking by sharing it with others and solicit students' reflections about their learning.

iv) Mc. Clintock and Black (1995) derived a model from several computer technology-supported learning environments. The Information Construction (ICON) model contains seven stages: a. Observation: Students make observations of primary source materials embedded in their natural context or simulations thereof. b. Interpretation Construction: Students interpret their observations and explain their reasoning. c. Contextualisation: Students construct contexts for their explanations. d. Cognitive Apprenticeship: Teachers help student apprentices' master observation, interpretation and contextualization. e. Collaboration: Students collaborate in observation, interpretation and contextualization. f. Multiple Interpretations: Students gain cognitive flexibility by being exposed to multiple interpretations from other students and from expert examples. g. Multiple Manifestations: Students gain transferability by seeing multiple manifestations of the same interpretations.

v) Planning and learning cycle. 4E's model

The four E's indicate exploration, explanation, expansion and evaluation. In the first stage, Explore, the students first encounter and identify the instructional task. Here they make connections between past and present learning experiences.
Lay the organizational ground work for the activities ahead and stimulate their involvement in the anticipation of these activities. The students have the opportunity to get directly involved with phenomena and materials. Involving themselves in the activities along with others, students build a base of common experience, which assist them in the process of sharing and communicating. The student observes, identifies, classifies in this phase.

In the second stage, Explain, is the point at which the learner begins to put the abstract experience through which he or she has gone/into a communicable form. Communication occurs between peers, the facilitator or within the learner himself.

In the stage three, Expand, the students expand on the concepts they have learned, make connections to other related concepts and apply their understandings to the world around them.

And lastly Evaluate, the fourth "E", is an ongoing diagnostic process that allows the teacher to determine if the learner has attained understanding of the concepts and knowledge. Evaluation and assessment can occur at all points along the continuum of the instructional process.

This model is simple, thorough, convenient and conducive to use in the classroom and has considerable potential to have an effect on the improvement in students' learning. It is not only a planning model but also a teaching model. This Constructivist model closely follows the original format of the Science Curriculum Improvement Study (SCIS), which is credited with the greatest student achievement
gains in major research studies and significant improvements in student science and their attitudes and inquiry skills when compared to similar experimental science programs and traditional science curricula (Shymansky et al., 1982; Bredderman, 1982).

1.2.3 Role of Constructivist approach in science classroom

A constructivist learning setting differs from the one based on the traditional model. In a constructivist classroom, learning outcomes not only depend on the learning environment but also on the knowledge of the learner. Learning involves the construction of meanings by students from what they see or hear may or may not be those intended. It is a continuous and an active process, which is influenced to a large extent by existing knowledge. Firstly current ideas of pupils are elicited using several strategies. These include pupils writing, expressing orally, card-sorting exercises, presenting pupils with descriptions of events and asking then to decide whether they are true or false, pupils producing posters on a particular idea. In this regard Driver et. al., (1994) identified five possible forms, depending on the outcome of the elicitation phase. These are:

- Developing existing ideas (if no misunderstandings are apparent);
- Differentiating between existing ideas (where two or more scientific ideas may be seen as one by pupils, e.g. dissolving and melting);
- Integrating existing ideas (where pupils may hold several ideas relating to one scientific ideas);
• Changing existing ideas (where pupils hold ideas which differ from the scientifically accepted ideas); and

• Introducing new ideas

After elicitation phase, the most difficult thing is changing existing ideas. Among the various methods, the most prominent ones are socratic questioning and introducing discrepant event in order to induce cognitive conflict, disequilibrium or dissonance in the minds of pupils. These approaches will help in the modification of existing ideas and in construction of new ideas. After the evaluation of the ideas, they are applied in new situations. Later the new idea is compared with previous ideas. Thus meanings, once constructed, are evaluated and can be accepted or rejected. Learners take the final responsibility of their learning (Driver ard Bell, 1986). The process of construction of new ideas is shown in the figure below:
Figure 1.5 The constructivist teaching model developed by the children's learning in science project team.

Source: Driver and Oldham (1986).

During the process of learning the students actively participate in various activities both individual and group work; share their feelings and ideas, reconstruct the meanings whenever required. There is no single approach or strategy used in a constructivist classroom, it is an eclectic approach made use of with a variety of methods, strategies and techniques but following the principles of constructivist approach. During the process of construction of meanings, the students make use
of various process skills and develop positive attitudes. There is every chance provided to practice and understand the nature of science and inculcate scientific attitude among the students.

Various educators and cognitive psychologists have applied constructivism to the development of learning environments.

Jonassen (1991) isolated a number of design principles:

- Create real-world environments that employ the context in which learning is relevant;
- Focus on realistic approaches to solving real-world problems;
- The instructor is a coach and analyzer of the strategies used to solve these problems;
- Stress conceptual interrelatedness, providing multiple representations or perspectives on the content;
- Instructional goals and objectives should be negotiated and not imposed;
- Evaluation should serve as a self-analysis tool;
- Provide tools and environments that help learners interpret the multiple perspectives of the world;
- Learning should be internally controlled and mediated by the learner.

Wilson and Cole (1991) provide a description of cognitive teaching models, which
"embody" constructivist concepts. The following concepts central to constructivist design, teaching and learning were isolated:

- Embed learning in a rich authentic problem-solving environment;
- Provide for authentic versus academic contexts for learning;
- Provide for learner control;
- Use errors as a mechanism to provide feedback on learner's understanding.

Brooks et al., (1993) gave the following suggestions for constructivist classroom:

- Student autonomy and initiative are accepted and encouraged.
- The teacher asks open-ended questions and allows wait time for responses.
- Higher-level thinking is encouraged.
- Students are engaged in a dialogue with the teacher and with each other.
- Students are engaged in experiences that challenge hypotheses and encourage discussion.
- The class uses raw data, primary sources, and manipulative, physical and interactive materials.
- The goal of the learner is to regurgitate the accepted explanation or methodology expostulated by the teacher.
Brooks and Brooks (1993) offered an interesting comparison of the visible differences between "traditional" classroom and "constructivist" classrooms. Their comparison is as follows:

- Students primarily work in groups unlike individually as in traditional classroom
- Curriculum is presented whole to part with emphasis on the big concept whereas in traditional classroom it is vice versa.
- Pursuit of student questions is highly valued whereas in traditional classroom strict adherence to a fixed curriculum is valued.
- Curricular activities rely heavily on primary resources unlike relying only on text books.
- Students are viewed as thinkers with emerging theories about the world (Cognitive apprentices) unlike its counterpart.
- Teachers are information dispensers and assess only to validate student lessons in traditional classroom where as a constructivist teacher generally behave in interactive manner mediating the environment for students and seeks student's point of view in order to understand student learning for use in subsequent conceptions.

Jonassen (1994) summarizes the following principles illustrating how knowledge construction can be facilitated:

- Provide multiple representations of reality;
• Represent the natural complexity of the real world;

• Focus on knowledge construction, not reproduction;

• Present authentic tasks;

• Provide real-world, case-based learning environments, rather than predetermined instructional sequences;

• Foster reflective practice;

• Enable context and content dependent knowledge construction;

• Support collaborative construction of knowledge through social negotiation.

Ernest (1995) in his description of the many schools of thought of constructivism suggests the following implications of constructivism which derive from both the radical and social perspectives:

• Sensitivity toward and attentiveness to the learner's previous constructions;

• Diagnostic teaching attempting to remedy learner's errors and misconceptions;

• Attention to metacognition and strategic self-regulation by learners;

• The use of multiple representations of mathematical concepts;

• Awareness of the importance of goals for the learner, and the dichotomy between learner and teacher goals;
Awareness of the importance of social contexts, such as the difference between folk or street mathematics and school mathematics.

Honebein (1996) describes seven goals for the design of constructivist learning environments:

- Provide experience with the knowledge construction process;
- Provide experience in and appreciation for multiple perspectives;
- Embed learning in realistic and relevant contexts;
- Encourage ownership and voice in the learning process;
- Embed learning in social experience;
- Encourage the use of multiple modes of representation;
- Encourage self-awareness in the knowledge construction process.

It is understood from the above description that constructivism unlike the conventional method of teaching involves exploration of students' preexisting ideas and their construction or reconstruction accordingly using various child centered strategies of teaching. The student autonomy and initiative are accepted and encouraged in the classroom. Thus this innovative approach will result not only in developing cognitive abilities but also to modify attitudes, increase self-confidence and decision making ability among the students.
1.2.4 Role of teacher in a constructivist classroom

In the constructivist classroom, the role of teacher also demands new orientation to suit the modern temper and times. Almost all students in one way or another construct their own meanings while acquiring knowledge. It is a very valuable mental activity of pupils, which should not be ignored thoughtlessly. It is then up to the pupils to link and interlink concepts by developing strategies to help themselves in construction of their new knowledge. This in other words, means that knowledge is constructed and reconstructed progressively in the presence of the teacher.

The teacher becomes a guide for the learner, providing bridging or scaffolding, helping to extend the learner's zone of proximal development. The student is encouraged to develop metacognitive skills such as reflective thinking and problem solving techniques. The independent learner is intrinsically motivated to generate, discover, build and enlarge her/his own framework of knowledge. The teacher is a facilitator or coach in the constructivist learning approach. The teacher guides the student, stimulating and provoking the student's critical thinking, analysing and synthesising throughout the learning process. The teacher is also a co-learner.

More emphasis is on organizing and meaningful learning than mechanical learning, emphasis on improvement of thinking than the attainment of narrowly conceived specific understandings and skills will be laid by the teacher. Right concept formation, application of scientific knowledge to unknown situation, designing and executing varied problem solving procedures are encouraged in the learning process. Over all a swing towards self-study, self-understanding and
self-education among students rather than authoritarian or dominated teaching
learning process by teachers is found in a constructivist classroom.

From the above discussion it is clear that in constructivist approach of science
learning, the students are given utmost freedom and ownership to what they learn
and the role of the teacher is to provide such experiences that give them an
opportunity to construct knowledge. In this process students make use of science
processes to construct knowledge, resulting in not only learning of concepts but
also a better understanding of nature of science and favorable science attitudes
were developed among the students.

1.3 Rationale and significance of the present study

The aims and objectives of science education at secondary level spelt out
were unfortunately not implemented properly. In spite of the effort made by many
committees and commissions as listed earlier (pp.8,9), the quality of science
education is not satisfactory. After the District primary education project intervention
programme there is a change in the textbooks, role of the teacher, involvement of
community and so on. The textbooks are activity based, inclusion of learner-centered
teaching learning process and increased utilization of community resources. But
still the change is not up to the mark. In this connection both at international and
national level, changes were emphasized in the teaching and learning process
and also in content standards. The National Science Education Standards (1996)
emphasized the following changes in teaching and content standards laying more
emphasis on
• Understanding and responding to individual student's interests, strengths, experiences and needs.

• Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes.

• Guiding students in active and extended scientific inquiry.

• Providing opportunities for scientific discussion and debate among students and continuously assessing student understanding.

• Supporting a classroom community with cooperation, shared responsibility and respect.

• Understanding scientific concepts and developing abilities of inquiry.

• Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives and history and nature of science.

• Integrating all aspects of science content.

• Implementing inquiry as instructional strategies, abilities and ideas to be learned.

At national level National Curriculum Framework for School Education, 2000 brought out by the National Council of Educational Research and Training (NCERT) emphasized viewing the child as a constructor of knowledge. Learning of science up to secondary stage needs to be replaced by learning of science and technology
in view of strong organic linkages between the two. It also recommended the following:

- Scientific attitudes and skills should be developed.

- Students are needed to be exposed to the nature and structure of science and the support it provides to the technological developments.

- Learning of science would be built around natural and social elements of environment.

- Focus would be on understanding of concepts and applications in the areas of matter and its properties, energy, relationship of various physical processes and the technological applications of principles of science.

- Science, technology, society and environment would coalesce in teaching and learning of science at secondary stage.

- Practical activities to be chosen should have relevance for further life through acquisition of skills and values.

- Emphasis on the 'learner centered approach' commensurate with the physical, mental, social and emotional development of learners in relevant age groups. In other words, there needs a shift of emphasis from information based and teacher-centered education of process centered and learner friendly education. Learners are needed to be encouraged to work both individually as well as in groups.
• Critical, creative and generative thinking has to be developed.
• Improvisation should be encouraged but designing would also be provided as a component in exploration.
• Flexibility in experimentation needs to be widely promoted.
• Teachers could help the learners devise appropriate experimentation and activities within and outside the school.

The present science education is far away from the above vision. Science is being taught in the schools as a body of established facts obtained by individuals using infallible methods. The present classroom practices emphasize on the product side of science rather than the method of acquiring the knowledge, which is the scientific method that forms the process side of science. In spite of several recommendations by many associations, AAAS (American Association for the Advancement of Science), SAPA (Science A Process Approach), NSTA (National Science Teachers Association) to develop science process skills, science related attitudes, understanding of nature of science along with acquisition of knowledge, still there is a very little chance provided to the learners to acquire the above.

In the conventional classroom, the classes are usually driven by “teacher talk” and depend heavily on textbooks for the structure of the course. Teachers serve as pipelines and seek to transfer their thoughts and meanings to the passive students. Thus, there is little room for student initiated questions and independent thought or interaction between students. Added to this the present curricula in science and
mathematics is overstuffed and undernourished (NCERT, 1968). They emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities. Above all there is no scope of understanding the misconceptions found among the students in the conventional method of teaching science.

Apart from the above observations it was also found (Sood, 1964) that the teachers do not concentrate on the process of learning by students and also overlook the misconceptions among them. The Chinese proverb "Do not give the fish but teach the person how to catch a fish" can be remembered here. Teaching the children how to learn is important than providing the facts to them. It is expected to raise the application abilities among the children learning science and technology to meet the aspirations of the day. Besides this, in the present competing world, there is a need of objective, critical and an intellectual mind i.e. a proper scientific attitude.

All the above ideas and processes occur repeatedly in constructivist writings. Even the students who score well are unable to successfully integrate or contrast memorized facts and formulate real-life applications outside the school - room (Yager, 1991). It was also found that practical knowledge and school knowledge are becoming mutually exclusive; many students see little connection between what they learn in the classroom and with their real life.
One proposed solution for the problem is to prepare students to become good adaptive learners. Obviously the traditional teacher-as-information-giver, textbook guided classroom has failed to bring about the desired outcomes of science education. An alternative is to change the focus of the classroom from teacher dominated to student centered using a constructivist approach. Studies have proved that constructivist approach is effective in the development of science attitudes and achievement by using various methods or strategies.

An attempt was made to study the effectiveness of constructivist approach in Indian context at secondary school level to find out whether this method would improve the students' understanding of nature of science, demonstrate a superior understanding of basic science concepts, use and understand basic processes of science better, can apply science concepts and processes in new situations, have more positive attitudes of science, science study, and science teachers, develop better science process skills including observing, reasoning, inferring, interpreting, proposing solutions, and predicting consequences, and have more complete views of the nature of science.

1.4 Statement of the problem

The present investigation is titled as

"EFFECTIVENESS OF CONSTRUCTIVIST APPROACH ON STUDENTS' ACHIEVEMENT IN SCIENCE, SCIENTIFIC ATTITUDE AND PERCEPTION OF NATURE OF SCIENCE AT SECONDARY LEVEL".
1.5 **Operational definitions of the terms used**

A number of terms and concepts have been used in the study. To convey the specific meaning, the terms and concepts used in the present study have been defined operationally as follows.

i) **Constructivist approach**

Constructivism is a view of learning based on the belief that knowledge is not a thing that can be simply given by the teacher at the front of the room to students in their desks. Rather, learners through an active, mental process of development construct knowledge; learners are the builders and creators of meaning and knowledge. The teacher is a co-participant, facilitator unlike the conventional one. The student is an active participant who explores, constructs the meaning, explains it and expands the knowledge with the help of the questions posed by the teacher. Constructivist approach is a pupil-centered method of teaching.

ii) **Achievement in science**

Achievement indicates the attainment of the objectives like knowledge, understanding, application and skill. An achievement test in the selected content including all the above four levels of objectives was constructed by the investigator. Thus achievement in science in the present study is the total score obtained by the students in the achievement test constructed by the investigator.

iii) **Perception of nature of science**

Perception of nature of science means the way the students perceive or
understand the nature of science. In the present study perception of nature of science pertains to the following aspects:

a. Characteristics of science
b. Scientific methods/processes
c. Use of scientific discoveries
d. Application of science in daily life
e. Role of science in society and its impact on human beings.

iv) Science Process skills

In science, the ways of thinking, measuring, solving problems and using thoughts are called processes. Among the various basic and integrated skills, the following intellectual skills were selected for the present study.

a. Observing
b. Inferring
c. Predicting
d. Hypothesizing
e. Interpreting and reasoning
f. Reasoning

The science process skills in the present study are the total sum of the above process skills in the developed test.

v) Scientific attitude

Scientific attitude is “the cognitive attitude or belief about thinking and has
also affective and behavioral aspects" (Guilford, 1967). Among the various scientific attitudes listed earlier (p.5) the following were selected for the present study:

a. Curiosity

b. Rationality

c. Willingness to suspend judgment

d. Open-mindedness

e. Objectivity

f. Perseverance and

g. Free from superstitions.

The scientific attitude in the present study is the total sum of the above components in the developed test.

vi) **Attitude towards science**

Gardner (1975a) defined attitude towards science in the following manner:

"We may regard a person's attitude to science as a learned disposition to evaluate in certain ways objects, people, actions, situations or propositions involved in learning science."

The term attitude towards science is composed of two words - 'attitude' and 'science'. Attitude according to Thurstone (1948) is the degree of positive or negative effect associated with some psychological object. Object here is 'science' as a discipline.
Hence, "Attitude towards Science is the generalized attitude towards the universe of science content and being measured in terms of its favorableness estimated from the scores obtained by the subject on an attitude scale towards science".

1.6 Variables included in the study

(A) Independent variables

i. Constructivist approach aims at improving achievement in science, perception of nature of science, science process skills, scientific attitude and attitude towards science.

ii. Gender

(B) Dependent variables

Effect of constructivist approach is studied on the students' achievement in science, perception of nature of science, science process skills, scientific attitude and attitude towards science.

1.7 Objectives of the study

With an insight into the philosophical, psychological and pedagogical bases of constructivism, the research undertaken aimed to study a few research bearing questions, which may throw more light upon constructivism as an approach to learning. These are reflected in the form of objectives given below:
1. To develop science lessons based on constructivist approach in the selected units of science for eighth standard students.

2. To study the effectiveness of constructivist approach on the students' achievement in science.

3. To study the effectiveness of constructivist approach on the students' perception of nature of science.

4. To study the effectiveness of constructivist approach in developing science process skills among the students.

5. To study the effectiveness of constructivist approach in developing scientific attitude among the students.

6. To study the effectiveness of constructivist approach on the students' attitude towards science.

7. To study the interaction between 'gender' and 'group' with reference to achievement in science, perception of nature of science, scientific attitude, science process skills and attitude towards science.

8. To examine the relationship among achievement in science, perception of nature of science, science process skills, scientific attitude and attitude towards science.

1.8 Hypotheses formulated for the study

The following research hypotheses were formulated in pursuance of the broad objectives of the study:
H1: The constructivist approach does have a positive effect on the achievement of students in science.

H2: The constructivist approach does have a positive effect on the students' perception of nature of science.

H3: The constructivist approach does have a positive effect on the development of science process skills among students.

H4: The constructivist approach does have a positive effect on the scientific attitude of students.

H5: The constructivist approach does have a positive effect on the students' attitude towards science.

H7: There is an interaction between 'gender' and 'group' on students' achievement in science, perception of nature of science, scientific attitude, science process skills and attitude towards science.

H9: There is a positive relationship among achievement in science, perception of nature of science, science process skills, scientific attitude and attitude towards science.

In the next chapter i.e. review of related literature, researches related to the present study are reviewed.