CHAPTER ONE
THEORETICAL BACKGROUND OF THE STUDY

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This chapter provides the theoretical framework of the study undertaken wherein the nature of Science and Science Education are discussed with their scope and philosophical bases. The status and trends in science education is discussed highlighting the pedagogical practices that dominate in the classrooms and the research endeavours in the field. Since developing the teachers’ competence in science was the main focus of the study, the perspectives on science teaching competence, along with the existing science education curricula and training inputs provided at pre-service and in-service teacher education are discussed in detail.

Against the theoretical background evolved, the rationale and significance of the study is provided. The objectives and the hypotheses to be pursued in light of the problem stated are included as a part of this chapter.

1.1 NATURE OF SCIENCE AND SCIENCE EDUCATION

1.1.1 Nature of Science

Science is a branch of knowledge and is characterized by its own nature and structure. Science is a systematically organized body of knowledge. Also, science has its own processes to generate knowledge. Science is characterized by (i) Certain central concepts (ii) Unique local structure (iii) Distinct criteria to test its propositions and (iv) well established techniques and skills (Hurd, 1970). Science is a thorough quest into natural phenomena, having a core of valid concepts, distinct criteria to test with a purpose of linking observable hypothetical propositions, by applying established techniques. Ordered propositions befitting into the existing body of knowledge merge themselves forming the ground to produce new propositions.

The logical structures of science are ever growing and self generate, through more or less by synthetic verifications. So science by its nature, juxtaposes the
structure and processes of its generation. Structure of science as scientists talk, has been taken as the conceptual organization of knowledge and the enquiry processes giving rise to it (Kumar et al, 1992). In each science, there are patterns of inquiry through which each one gets organized, problems are solved and discoveries are made. These patterns of inquiry are available not only to bring order in acquired and accumulated information, but also to generate new knowledge. Conceptually organized body of knowledge and inquiry process are though inseparable, understanding of science is more a matter of appreciation of its mode of inquiry (Taba, 1964).

Similar to scientific knowledge conceptions of nature of science are tentative and dynamic: (1) Empirical nature (observation) of scientific knowledge, (2) Inference and theoretical entities, (3) Nature of scientific theories, (4) Scientific theories versus laws, (5) Creativity, (6) Subjectivity (theory-laideness), (7) Social and cultural influences forms just one exemplary set of aspects on which nature of science can be described.

Science is at least partially based on observation of the natural world. However, scientists do not have direct access to most natural phenomena. So many a times, inferential or theoretical frame works are used. Observations are descriptive statements about natural phenomena that are directly accessible to the senses or extensions of the senses. For example, objects released from any point above ground level tend to fall to the ground. By contrast, inferences are statements about phenomena that are not directly accessible to the senses. For example, objects tend to fall to the ground because of gravity. The notion of gravity is inferential in the sense that it can be accessed and/or measured only through its manifestations or effects.

An understanding of crucial distinction between observation and inference is a precursor to making sense of a multitude of inferential and theoretical entities and terms, that inhabit the worlds of science. Examples of such entities include atoms, molecular-orbitals, species, genes, photons, magnetic fields and gravitational forces. (Hull, 1998, p 146). Scientific theories are well established highly substantiated internally consistent systems of explanations (Suppe, 1977). Theories serve to explain
large sets of seemingly unrelated observations in more than one fields of investigation. Theories, by contrast are inferred explanations, for observable phenomena or regularities on those phenomena. For example, the Kinetic molecular theory serves to explain Boys law. Theories and laws are different kinds of knowledge and one does not become the other. The development of scientific knowledge involves making observations of nature. None-the-less generating scientific knowledge also involves human imagination and creativity. So science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. The leap from atomic spectral lines to both model of the atom and its elaborate orbits and energy levels is an example. Scientists’ theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations actually influence their work. So, contrary to common belief, science never starts with neutral observations (Popper, 1992).

So, altogether the structure of science is ever increasing, enriched accumulization of content categories such as facts, generalization, concepts, theories, laws etc.

Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture. Science is so effected by and do effects various elements of culture such as social fabric power structures, politics, socio economic factors, philosophy, and religion. One of the most widely held misconceptions about science is the existence of the scientific method. The myth of the scientific method is regularly manifested in the belief that there is recipe like stepwise procedure that all scientists follow when they do science. This notion was explicitly debunked: there is no single scientific method that would guarantee the development of infallible knowledge (AAAS, 1993; Bauer, 1994; Feyerabend, 1993; NRC, 1996; Shapin, 1996; all as cited in Lederman et al., 2002). It is true that scientists observe, compare, measure, test, speculate, hypothesize, create ideas and conceptual tools, and construct theories and explanations. However there is no single sequence of activities (prescribed or otherwise) that will unerringly lead them to functional or valid solutions or answers, let alone certain or true knowledge (Lederman et al., 2002).
Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge including facts, theories and laws, is subject to changes. Indeed contrary to common belief, scientific hypotheses, theories and laws can never be absolutely proven irrespective of the amount of supporting empirical evidence (Popper, 1963).

So, understanding nature of scientific knowledge or science is an issue of far reaching concern. Conant (1951) rightly comments that as far as the issue related to nature of science is concerned, it is not enough for one to be informed about science, but that one should understand science. And what is to be understood is the nature of science that is the presuppositions, methods, structure and limitations of science. Herron (1969) says, anything as complex as the nature of scientific knowledge or ‘inquiry’ is capable of being seen from a variety of points of views. So, it is difficult to speak of the nature of science in common terms. Scientific processes are activities related to the collection and interpretation of data and the derivation of conclusions. Nature of science in comparison, is related to some other aspect which is concerned with values and epistemological assumptions underlying these activities (Abd-El-Khalick et al., 1998; Chiappetta, Koballa & Collette, 1998).

Different researchers use different models, to give shape to the nature of science; thus the interpretation of research findings must always be presented in terms of the theoretical model employed (Cobern, 1989). A list of eight points of one such model of nature of science (Kimball, 1967) is given below.

(i) The fundamental driving force in science is curiosity concerning the physical universe. It has no connection with outcomes, applications, or uses aside from generation of new knowledge.

(ii) In the search for knowledge, science is process oriented, dynamic, ongoing activity rather than a static accumulation of information.

(iii) In dealing with knowledge, as it is developed and manipulated, science aims at ever-increasing comprehensiveness and simplification, emphasizing mathematical language as the most precise and simplest means of stating relationships.
(iv) There is no one "scientific method" as often described in school science textbooks. Rather, there are as many methods of science as there are practitioners.

(v) The methods of science are characterized by a few attributes, which are more in the realm of values than techniques. Among these traits of science are dependence upon sense experience, insistence on operational definitions, recognition of the arbitrariness of definition and schemes of classification or organization, and the evaluation of scientific work in terms of reproducibility and of usefulness in furthering scientific inquiry.

(vi) A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.

(vii) Science has a unique attribute of openness of mind, allowing for willingness to change opinion in the face of evidence, and the openness of the realm of investigation, unlimited by such factors as religion, politics, or geography.

(viii) Tentativeness and uncertainty mark all of science. Nothing is ever completely proven in science, and recognition of this fact is a guiding consideration of the discipline.

1.1.2 Nature of Science Education

Science profoundly penetrates into every activity of living world, so much and so that there is an ever increasing thrust on science education to fulfill these needs of sciencing the civilized world. Science, as a school subject has a crucial role in education. Science provides an exhaustible storehouse of knowledge and human thinking when we consider it from the intellectual point of view. Science helped mankind to expose infinite avenues of nature both living and nonliving. It takes him to the world that is perceivable, as well as to the world beyond human perception. In the course, it satisfies human curiosity and provides him a disciplined intellectual exercise. So, it has disciplinary effect on the minds of people in the civilized society. Study of science awakens interest in the subject, its pursuit demands persistent efforts - diligence and patience. For example, say, in a simple process of science - the experimentation - it warrants ones careful observation, perseverance, concentration,
honesty, impartial logical judgement. These virtues are useful for guiding him to live as an efficient social individual in the society. Training in science teach one how to think with imagination and seeks productive thinking to find the solution to a problem. And in doing so we see a discipline-the control of ones capacity to make it, do what one wants it to do (Nourse, 1960). Many scientific discoveries have bearing upon deepest thought of man.

So, science can bring behavioural change in the learner, which can enrich his personality aspects. It gives opportunity for search of truth, developing problem solving skill, creative thinking, constructive imagination etc. Even our habits, attitudes, literatures, art and culture are all have been very much effected and influenced by science.

The continuous research and advancements in the field of science and technology had led to greater growth and application of science in contemporary society. Because of this, science as well as science education becomes a priority area. The process of education is achieved through a curricular system for school education through a set of selective language and optional core subject. Both in school and college level curriculum science as a subject of study occupies eminent place. Actually, the term science education stands for integrated concept of linking science with education using psychology. So, if to be educated is the goal of common man, then to be educated in science is the goal of modern man (Vaidya, 1970).

Science education is supposed to perform twofold task (Ganguli and Vashishtha, 1991). At individual level, science education is expected to give individuals a firm grasp of the concepts and processes of science and impart them the ability to use the scientific method of problem solving and the techniques of observation and experimentation in handling problem of comprehension on life. It needs cultivation of scientific enquiry, logical reasoning, habit of judging beliefs and opinions on available evidence, courage to admit facts, readiness to discard unfounded theories, to recognize limit of reasoning power itself. At societal level, science is a universal activity not being confined to state or national frontiers. When we exploit scientific enquires commercially, science helps for strengthening of
national economy, creation of resources, potential for a more human global outlook. So, science education in a broader outlook equip the individuals in the construction of the society, which is free from poverty, hunger, disease etc and evils such as violence, exploitation, oppression etc. Hence the aims and objectives of science education is to be analysed on the basis of these requirements. The explosion of knowledge where-in the quantum of knowledge is being multiplied exponentially, it apparently seems that the main objectives of teaching science is to impart wide bulk of scientific knowledge and as such a suitably designed teaching-learning practices prevalent in schools are taken to be well approved. But in fact the emphasis of science education should be on development of abilities and dispositions of mind, not just transfer of dead subject matter. Therefore science education must primarily have a concern for educating the mind and thinking rather than acquisition of isolated pieces of scientific knowledge, however large be the quantum of it.

This issue is addressed by introducing a better terminology - ‘sciencing’. Sciencing means engaging in exploration of the material universe for the purpose of seeking orderly explanations of the objects and events observed, and testing these explanations (Lansdown et al., 1971). Science teaching in school should be a process of sciencing the children (Brandwein et al., 1958; Lansdown, 1991). And for sciencing, science means a method of investigating phenomena and not a product and the student must be allowed to emulate the scientist (Gallagher, 1964). Therefore, the object of all science is to coordinate our experiences and bring them into a logical thinking (Einstein cited by Haltan and Roller, 1958).

Sciencing in fact embraces its ‘substantive’ and ‘syntactical’ structures. (AAAS, NRC, Brandwein et al., Lansdown et al.; as cited in Pachaury, 1999). The former represents the conceptual products to which scientific terms, concepts generalization, laws, principles, theories, conceptual schemes etc belongs to. Syntactical structure refers to process structure, which involves observing, measuring classifying, inferring etc. So, science education of school going children have to reflect its substantive as well as its syntactical structures. For true sciencing to take place in the schools, the children should necessarily be engaged themselves in the
processes of sciences for construction of scientific realities. Thus, in brief, it can be summarized that

- Science as a great human enterprises has fields of application which encompasses each and every walk of life.
- Study of science will have such an impact on the minds of everybody which could develop qualities of broad mindedness in addition to bundles of universally accepted knowledge of nature.
- Science as a school subject is not only meant for mere transfer of knowledge but also for sciencing the new generation. Science education should be channelised towards developing thinking abilities and a mindset typical to the way of science.

The syntactical structure of science in the context of science education mainly indicate the processing of science. The process of science consists of attitudes and methods of inquiry. Science stems out of human urges and needs which drive people to seek rational answers to their questions. This dynamic-almost compulsive-involvement of people searching for answers results in certain condition of readiness of mind for a typical type of discovery activities which is termed as scientific attitude. For example, any investigator as he knows more and more discovers that he knows so little. This fosters certain scientific attitudes such as ‘Humility’ and ‘Skepticism’. Human tendency is usually to get discouraged when he meet failure or when the progress to resolve a problem after a prolonged study to solve it become less. But scientist do view such failure as realistic and apply his effort with a never-ending zeal. It thus originates another attitude - the ‘positive approach to failure’.

So scientific attitudes can most often be characterized by a list of component attitudes such as objectivity, open-mindedness skepticism, willingness to suspend judgment if there is insufficient evidence, etc. (Okay, 1982). Richard H. Hampkin Jr. (1938) study has brought out some 92 scientific attitudes. Ebel (1935), Noll (1935), Davis (1942), Caldwell and Curtis (1943), Vaidya (1976) tried to bring out brief and accurate list of elements of scientific attitude (all as cited in Bhasker and Marlow, 1996). Among the several attributes pointed out by many studies, the commonly referred attributes are curiosity, rationality, skepticism, positive approach to failure,
critical mindedness, Open mindedness, Intellectual honesty, Willing to suspend judgement, Objectivity, Accuracy of perception, Looking for true cause and relationships, Humanity and reverence for life etc.

Scientific inquiry can be defined as a search for the truth or knowledge. Emphasis is placed upon the aspect of search, rather than on the mere acquisition of knowledge. What? How? Why? are mainly the three types of questions which seems to be essence of science-enquiry, that leads to application of an appropriate strategy such as scientific method. A scientific method suggest discrete steps such as: (a) Sensing the problem, (b) Collection of data, (c) Selecting a working hypothesis, (d) Testing the hypothesis (the experiment), (e) Establishment of law theory, (f) Predicting and validating this prediction. As already pointed out there is no such single method that would guarantee the development of this intellectual process. However, creativeness plays a role while following steps of scientific method. The kind of artificial dissection of thinking process like the steps given above is nothing but a pedagogical device to show more clearly how facts are woven into ideas.

The next processes of scientific enquiry are idiosyncratic and so difficult to describe. But, they usually include relentless testing of data, scientific reasoning and the sue of controlled experimentation for searching cause and effect. Therefore, the interest of science is basically focused in finding cause and effect relationships between the seemingly independent and fragmented data they collect. Whenever possible, science uses its greatest device for testing its ideas of cause and effect in the controlled experiment which is the basic process of enquiry. This search for cause and effect is centred on the use of combination of inductive and deductive reasoning.

Experimentation is the prime activity in science. In the process of conducting experimentation it requires one to perform so many basic skills as a part of carrying out the process. These skills includes some simple process such as observing, hypothesizing, experimenting, classifying, inferring, predicting and communicating. These activities forms a set of most fundamental processes of learning science and hence known as science process skills. At complex level, sensing the problem, identifying variables, hypothesizing, interpreting data, designing procedure, drawing
conclusion etc also forms the set of important integrated science process skills. Using time/space relationships, using numbers, formulating and using models etc are a few other process skills.

The products of scientific processes as discussed above are the accumulated, systematized and tested body of knowledge are categorized into different fields of science. Facts, concepts, generalizations, and principles are the results of constant scientific testing of data. These component content categories then become the raw materials that scientists use in their search for broader conceptual schemes in pursuit of knowledge, which they call theories and laws. These theories and laws are perennially scrutinized to see if they are valid.

Facts are very important in the process of scientific enquiry. Scientific facts are those which must be observable and must be demonstrable (repeatable). When a series of facts seem to fit together and show some pattern of relationship it becomes generalization. They are based upon so many direct observations and repeatable demonstrations. That is why, often generalizations are used interchangeably with facts.

Concepts, in some way, are more than generalizations; in the sense that concepts are used more to describe mental processes than scientific definitions. It is just reduction of events to a recognizable configuration. The scientific principles or rules describe relationship between concepts. Laws are universal empirical proposition. Theories are broad explanations to facts, which can generate predictions. Theories achieve one of the broad explanations that combine apparently related and isolated facts, generalizations, principles etc into more inclusive models or conceptual schemes. Theories are tentative, subject to rejection, reformation and acceptance by further verification. Hence laws and theories are constantly changing as they are modified or discarded and new ones take their place. This is the essence of science. The only constant in science is change (Carin and Sund, 1970).

**1.1.3 Science Teaching**

Teaching, in general is an exclusive and broad phenomenon. Its conception is also subject to remarkable change as a consequence of the huge science and technological development and the relative changes expressed in the form of
innovative out-looks of modern society. The following prescriptive features of the complex phenomenon of teaching are considered to structurize the process of science teaching in the present study:

• Teaching – learning process seems to be dipole in nature, wherein learning should occur as a consequence of teaching.

• The process of teaching is more centralized in classroom instruction, where the core interactive sessions takes place between teacher and pupil.

• Teaching is more inclusive concept, not just have a reference to the classroom instruction which is interactive, but do covers the pre-active and post active (that is planning and evaluating works) processes also.

• The epicenter of teaching-learning dipole can be considered to be lying shifted towards teaching as long as the classroom instructional activities (teaching) are conducted with an intent of modifying students behaviour. Thus any issues related to teaching-learning process can as well be regarded as an exclusive issue centred on the process of teaching only.

• When the teacher seeks to bring his pupils into the context of learning a subject matter, there are number of things which are subjected to cause-effect relationships such as, Nature of children, Nature of teacher and Nature of subject matter. Specifically each subject has its own structure and processes of generating knowledge which influences both teacher and pupil. So how a subject is to be taught, to a greater extent is determined by its nature and structure.

• Science education can be considered as predominantly depending upon the process of science teaching and hence on science teacher, even though other variables such as context/situation generally have a considerable role on the product the learning out-come of the subject.

   In recent decades the major goal of science instruction is spelt in terms of scientific literacy. In one of the comprehensive literature the following dimensional definition of scientific literacy is formulated (Showalter as cited in Cohen, 1978): A scientifically literate person is one who-

   - Understands the nature of scientific knowledge.
- Accurately applies appropriate science concepts, principles, laws and theories interacting with his universe.
- Uses processes of science in solving problems, making decision and furthering his own understanding of the universe.
- Interacts with the various aspects of his universe in a way that is consistent with the values that underlie science.
- Understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each and with other aspects of society.
- Develops a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life.
- Develops numerous manipulative skills associated with science and technology.

Then it can be presumed that the effective science teaching should ultimately be founded on three core criteria: understanding of the nature of scientific knowledge; understanding the content centered substantive structure of science and understanding of the processes of science which needs explicit efforts extending beyond text book content. So, effective science teaching should focus on all these three aspects.

Many educators assumed that the teachers notions about science which includes nature of science influences students understanding of science. Because, it includes understanding the major concepts of science, use of science concepts in daily life situations and understanding the generation of scientific knowledge (NSTA 1982) which forms some of basic objectives of science education. Perception of nature of science should be known to the teachers in order to guide their students in building right attitude towards science as well as scientific attitude, because it is the major goal of science education (Kimball, 1967).

The teaching of science then should focus at least on the following few aspects such as – the composition of perception of nature of science by students-Characteristics of science, Scientific method/processes, Use of scientific discoveries, Application of science in daily life, Role of science in society and its impact on human beings. In brief, a science teacher should thoroughly understand the nature of science in order to teach science effectively.
In science education students have to learn concepts ranging from simple definite concrete, sensory perceivable (Plants, animals, metals, chemicals etc) to purely abstract, indefinite, beyond sensory experiences (Atom, chromosome, energy, mutation, evolution, relativity, field, wave etc). Identifying attributes of concepts, and classifying and analyzing them on the basis of learnability, perceptivity, finiteness, abstractness etc is the foremost task of science teachers to initiate effective learning of science. Science concepts are both Taxonomic-classificatory type (eg: transition metals, mammal, elastic collision, visible spectrum, etc.) and Non-taxonomic-qualitative type (eg., mass, momentum, volume, etc.). For Taxonomic concepts it is meaningful to speak of positive and negative instances (eg., whale is positive example for mammal, but fish is a negative example). Non-taxonomic concepts have on the contrary only qualitative dimensions (eg., we can talk about zero momentum or some momentum or large momentum, but not positive or negative momentum). The distinction between taxonomic and non-taxonomic concepts is educationally fruitful because these two types of concepts involve different sequences of teaching operations. Science concepts may be either concepts by perception or observation (eg: iron, cat, stone, water, blue, root, etc.) or concepts by verbal definition that are similar to statement of principles or laws (eg. Boyles law, Darwin’s law, Newton’s law, Archimedes principle. Concepts by observations are commonly taught by presenting positive and negative instances of the concept. Concepts by definition and principles may be learnt by verbal means, but it needs to be stressed that the ability of the child to state or recognize the verbalization, is certainly not a sufficient condition and perhaps not even a necessary condition for establishing that learning has occurred.

So, classroom science teaching must begin by a thorough analysis of the content for major concept and principles to be developed, followed by certain teaching principles and approaches in an interrelated and integrated manner, by organizing appropriate teaching learning activities.

Science processes should form an integral part of general science teaching programme. Teachers should understand thoroughly each of the basic and integrated
process skills and adopt appropriate strategies to develop them among their students. Science instruction should be investigative and experimental type, which demands involvement of sensory-motor organs and a zeal of inquiry. If science is taught in this way student learn how to use their mind in addition to learning science concepts and principles. The teaching activities should be so structured that the child is forced to use his mind to formulate hypothesis, control variables, design experiments, make operational definitions, formulate models, interpreter data, and many more such cognitive processes. By doing so the child performs many mental operations.

Curry (1990), in his comments over science teaching at United States, says that the study of science provides a learner with opportunities to develop an understanding of our world that is the primary process of scientific inquiry by which science knowledge is gained. It involves basic skill of questioning, predicting, quantitative and qualitative observing, classifying, inferring, communicating and additionally integrated skill such as identifying and controlling for variables, generating procedures, planning strategies for testing hypothesis and answering questions as well as collecting and interpreting appropriate data.

So, all these implies that teaching of science should provide a kind of ground work for their future training in science-the scientific method of thinking, scientific attitude and temper and overall positive attitude towards science.

As already discussed scientific attitude represents the habit of scientific thinking expressed by affective behaviour of scientific mindedness. Queensland Board of Secondary School Studies (1974) recommends the development of attitudes (through learning experiences in science), which encourage the student to be—curious; rational; willing to suspend judgement; openminded; objective and honest in representing observations; ready to admit to error; tolerant of errors of others; receptive of limitations of man and science; persistence; cooperation; and critical awareness and demand for evidence to support claims. Similarly, developing positive attitude towards science is another important goal of any science teaching programme.

Attitude towards science represents the generalized attitude towards the universe of science content. It can be measured in terms of its favourableness
estimated from the scores obtained by the subject on an attitude scale appropriated, designed and developed for the purpose. It is a person’s attitude to science as a learned disposition to evaluate in certain ways objects, peoples, actions, situations or propositions involved in learning science (Gardner, 1975).

So with an expertise sense of view, if teaching of science is to be more meaningful, realistic and effective it should take into consideration all aspects of nature of science, and substantive – syntactical structure of science, as narrated in this section. All the teacher preparation courses and pre-service training programmes are supposed to provide a curriculum course structure with a scope to understand and imbibe the structure of science as a discipline. Information in this section also provides a fabric to generate, at a macro-level, the expected science teaching competencies, the main conceptual structure on which the present study is being build-up.

1.1.4 The Present Status of Science Teaching

Before carving out any rationale that could give a fairly real shape for conception of science teaching competencies, one has to advance still further in the present stream of discussion. The objective of such discussion is to know, what really it (science teaching competency) is and what it must ideally be. In the present study the science teaching competencies are to be build up on the basis of discrepancies criteria based on bridging the gap between the model of expected expert/theoretical predicted role and the actually performed/realized role of teaching science in secondary schools. So, a brief discussion on status of science teaching forms a precursor and pre-cognitive base.

Here, while discussing the status of science teaching, a necessary delimitation stems out from the fact that teaching differ from curricular responsibilities. The teacher is not equivalent to curriculum maker (one who formulates and decides upon instructional ends). The task of making curriculum involves many individuals, not just teacher, or many a time it does not even involves teacher. Although, teachers often interpret and operationalize the goal statements decided upon by others, classroom teachers are generally not responsible for selecting the goals of a school
system (McNeil et al., 1971). Thus here, the definition of teaching is restricted to the extent of teacher accomplishing ends of science education (transaction of curriculum), rather than deciding ends of science education (formulation of curriculum). Therefore any point of critical observation regarding state level curriculum, aims and objectives of science education, science text books set by state department etc falls beyond the preview of analysis of status of science teaching.

Few studies have pointed out the drawbacks of present condition of teaching the science subject in schools. It was found that secondary school students do not possess adequate understanding of nature of science (Cooley and Klopfer, 1963). There is inadequacy in understanding of nature of science among students as well as teachers (Machay, 1971; Bad, 1949; Kimbal, 1967 as cited in Ruba and others, 1981). The traditional science programme emphasize only the factual content of science but do not promote an understanding of nature of science.

Too often in science teaching, school teachers have stressed the products rather than the process of science (Carin and Sund, 1970). In spite of a revolutionary change which took place in 1960’s in upgrading science curriculum and mode of presentation of scientific knowledge, many studies later on, while discussing syllabus of science for Indian schools, pointed out the weakness of teaching science. The main issue was lack of keeping process oriented conceptual goals as one of the objectives of teaching. (Bhatnagar, 1970).

On the basis of review of above or many other such studies reveal that science teachers do not have good knowledge of nature of science and this lack of understanding among teachers in every way could affect the student’s perception of characteristics of science, scientific processes and methods, use of scientific discoveries, application of science in daily life, role of science in society and impact on human beings etc.

In one of the discussion regarding status of science teaching in USA the commentary reads like this:

“Science is not to be taught by word or mouth, or vegetables and fruit need no longer be grown on the black board. Instead, emphasis should be on hands-on and minds on experiences, frontal experiments, pupil
oriented first hand observations, drawing of conclusions during the course of experimentation, etc.”

Pressing of educational technology into service, use of calculators, teaching machines and micro computers, etc. are the other features that can be pointed out as resources of teaching which can be enhanced by forming resource centres (Vaidya, N., 1978). The problems faced by science education in developing countries are that, (i) about half of the teaching force in science is inadequate in content and pedagogy, (ii) Dominance of lecture method, (iii) neglect of community resources in day-to-day teaching. In Indian situation, the science education set up is more or less the same in all the states in the country. Some of the expert remarks regarding the present-day state of affairs in science teaching are as follow.

Science teaching has been and still oral in character with demonstration occasionally thrown in. There is very little practical work up to eighth standard. The element of investigation, training in the use and practice of the scientific method and even mastery of the research operation (discovery approach of learning) are conspicuous by their absence, even at those places where laboratory facilities and equipment are generous. Science teaching is based strictly on the prescribed textbooks, which the Students and teachers follow them slavishly (Vaidya, 1970). The training in scientific method, problem solving, creative thinking and the development of scientific skills, interests, attitudes and appreciation remain in an utter state of neglect. There is hardly any regular supervision and guidance offered to improve science teaching. And surprisingly this state of affairs is not fully changed even after a few recommendations made in at the national level, to improve science teaching in schools. (NCERT, 1988, 1988a and 2005)

It is also observed that children manifest staggering of the stages of cognitive development. Motor and stimulus deprivation during sensorimotor stage (0-2 years), and lack of representational experiences (indices, symbols, signs) during the pre-operational stage (2-7 years) result in reflecting delays in attainments of conservation, classification, seriation and transitivity behaviours by the children of seven years of age, who otherwise normally should have mastered these cognitive schemes.
Indian teachers perceive their primary task as illuminating the content of the textbook to their students and helping them to memorize the text (Clarke and Fuller, 1996). Curriculum transaction through telling or recitation does not provide an interactive learning environment for children. Therefore even though child centered and readiness programmes were launched, they failed to nurture cognitive growth of the school entrants. At times regression in cognitive functioning has been observed. For instance, a special study conducted on students of class nine (central school) and talented students of class seven (Jawaharlal Nehru Vidyakendra) had pointed out regression in intuitive thinking, as manifested in the situation of problem-solving related to the respiratory organelles of house-spider (Pachaury, 1999). Delay in the development of the logical thought results due to non-interactive learning conditions of the classrooms faced by children. Following salient features are listed on the basis of a brief review of the preceding discussions.

- Science teaching do not promote adequate understanding about nature of science among the students and among the teachers themselves, who do not possess this knowledge.
- Structure of science is both substantive and syntactical. But the issue of teaching science with more emphasis on product aspect rather than on processes of science is observed as a major draw-back in science teaching.
- Classroom instructional practices are predominantly centred on dispensing (lecturing etc) ready made factual knowledge (textual content) rather than formulation of conceptual understanding by facilitating interaction and construction of scientific knowledge.
- Activities for practicing of skills like observation, communications, experimentation, etc. meant for developing thinking operations such as scientific attitude, method of science, appreciation for science, etc hardly find any place in the present teaching situation in science classrooms.
- Facilities for motivating science teachers to improve their classroom teaching practices with the help of any comprehensive/systematized/standardized
pattern/resource/guidance are not found in the present system of school education except for some meagerly scattered specific projects.

On the whole it is observed that science is not taught in a way it should be taught. This opens to few questions such as where exactly the endeavor of improve teaching should be initiated? Or with whom the ultimate responsibility of improving classroom teaching is laid upon? In the personified entity, it is the science teacher for his excellence in profession, who is capable of going beyond syllabus and textbook and organize constructive learning situation through the real process of science, use variety of instructional materials, accommodates joyful experiences and evaluates the out comes. It is only the science teacher by gaining appropriate teaching competencies, can venture to do all these, with his veto power over the system of sciencing the new generation.

The status of science teaching in schools, is mainly determined by the quality of science teachers and more precisely on teaching abilities or competencies that these science teachers possess. So, it is rather imperative now to examine what are these science teaching competencies that we could think of as a prime factor for improving the overall status of science teaching.

1.2 SCIENCE TEACHING COMPETENCIES

1.2.1 The Meaning of Science Teaching Competencies

In order to derive a meaningful conceptual frame work for science teaching competencies, it is necessary to get into the meaning of competence. The earliest known notion of competence was just restricted to the rationale of performance based distinction between qualified and unqualified practitioners on the basis of public assurance (Curr-Sounders and Wilson, 1993). It is valued that competence can be deduced from the description of the chief distinguishing feature of the professions like ‘special competence, acquired as a result of intellectual training’ or as ‘specialized intellectual techniques, acquired as the result of prolonged training’. The frequent reference made to examinations as tests-of-competence suggests a view for professional competence as the specialized intellectual capability rather than a practical skill. Hence the apparent gap between being properly qualified and being
able to perform went unrecognized. Again another subtle distinction that exists is regarding the scope of a specific competence versus general competence. For the employers, claim to have competent staff may just imply that they would employ people generally competent as well as properly qualified. But for the service users the professional are considered as competent if they have had some satisfactory service from that person. (a) specific competence claims are usually intended to convey information about what a competent person can do without implying that he or she is competent beyond the area specifically mentioned (b) generic competence however is extensive. But in the case of professions where work is relatively homogenous, the difference between statements of general and specific competence is not confusing as one could be inferred from the other. But in professions where work is relatively heterogeneous, stating competencies in general statements become rather dangerous, and so a need arises to develop a profile of specific competencies. These profile of competencies clearly demonstrate those aspects of the job in which each professional is competent.

Oxford English Dictionary describe the word competent as – sufficient in amount, quality, or degree’. So the interpretation can lead to a positive meaning like ‘getting the job done’ to a negative meaning of ‘adequate but less than excellent’. Accordingly the differed connotation may be viewed with a two distinct mode of judging schemes. First type of mode is the Binary scale for judging where a person is judged to be either competent or not competent. The second type of judging is through Graduated scale where a person is judged by his position on a continuum from novice to expert. In addition to this, the meaning for competence as derived by Peter and Pearson is noteworthy to be mentioned here:

“People were generally competent by then get promoted until they reach the level at which they become incompetent. And if we think of continuum ranging from just knowing how to do something at the one end to knowing how to do something very well at the other, knowing how to do something competently would fall somewhere along this continuum”. (Peter, Pearson; 1984, p. 32)
Discussion so far, highlights that a professional person’s competence has at least two dimensions. The scope of competence which concerns what a person is competent in, the range of roles, tasks and situations for which their competence is established or may be reliably inferred. And secondly, the quality of competence which concerns judgments about the quality of that work on a continuum from being a novice (who is not yet competent in that particular task) to being an expert (who is acknowledged by colleagues as having progressed well beyond the level of competence).

Now an effort is made to apply and synchronize the features of professional competence to the situation of developing science teaching as a competence. A few terms which are used interchangeably with the term competence in normal circumstances, but are not actually implying the same meaning can be clarified as follows.

The meaning of Competence can be related to notion of ‘competencies’ like this – Competence has a holistic meaning when compared with the meaning of
competency. The former refers to a persons’ overall capacity, whereas the later refers to specific capabilities. However, the word competency can also be used either in a direct performance related sense or simply to describe any piece of knowledge or skill that might be constructed as relevant (Hermann & Kenyon, as cited in Curr-Sounders, 1993). Competence then must be distinguished from the competencies assessed in contemporary testing programmes. Competence is a general ability to coordinate appropriate internal cognitive, affective and other resources necessary for successful adaptation rather than a single ability or reproduce a piece of information on demand. Competence is command of pertinent knowledge and/or skills where the word command imply that the competent person not only possess the requisite competencies but is also able to use them (Short, as cited in Curr-Sounders, 1993). According to Gage (1963), teaching competence involves effective use of the various teaching skills.

Secondly, the meaning of competence is combined with the meaning of ‘performance’ as follows: Competence refers to what a person knows and can do under ideal circumstances, whereas performance refers to what is actually done under existing circumstances. So, competence embraces the structure of knowledge and abilities whereas performance subsumes as well the possesses of accessing and utilizing those structures and a host of effective motivational, attentional and stylistic factors that influence the ultimate responses (Messick, as cited in Curr-Sounders, 1993). Hence performance is directly observable whereas competence is inferable from performance (Gonzi et al., as cited in Curr-Sounders, 1993). And on the basis of this point of view, teacher performance involves the identification of teacher competence. But, in case of learning situations, it is true that a student’s competence might not be validly revealed in either classroom performance or test performance because of personal or circumstantial factors that affect behaviour.

In total, it can be summarized that the competence of professionals derives from their possessing a set of relevant attributes such as knowledge, skills and attitudes. These attributes which jointly underlie competence are often referred to as competencies. Therefore the competency means a combination of attributes
underlying some aspects of successful professional performance. But mere attributes of individual nor mere performance of series of tasks themselves constitute competence. Competence then integrate attributes with performance. (Gonzi et al., 1993, p. 5-6). So, the integrated in-depth structure of teaching a subject is a general ability to coordinate appropriately cognitive, affective and other internal resources necessary for successful adaptation of it. It can thus be better referred to as cluster of competencies rather than a single entity competence. Hence for indicating/abilities teaching of science we attribute the concept by name ‘Science Teaching Competencies’.

A precise form of descriptive definition for competencies as given in Directory of education (Carter V. Good, 1959) reveals that it is the ability to apply to practical situations the essential principles and techniques of a particular subject matter field. It includes those skills, concepts and attitudes needed by all workers regardless of their occupations or specific jobs. In specific jobs like teaching science those concepts skills and attitudes which are highly specialized and related directly to the single job classifications forms the competencies.

As already discussed teaching can be defined in many ways. If teaching is defined simply as a set of observable teacher behaviours that facilitate or bring about the pupil learning, the teaching competency then means an effective performance of all the observable teacher behaviours that bring about desired pupil outcomes. Thus, it involves effective use of the various teaching skills (Gage, 1963). So, teacher competency refers to the teacher behaviours that produce intended effects (Medly & Mitzel, 1963). Teacher competency is the ability of a teacher manifested through a set of overt teacher classroom behaviours which is resultant of the interaction between the presage and the product variable of teaching within social setting. It can thus be pointed out that teaching process is determined by knowledge, a set of abilities, attitudes and skills which in turn determine pupil outcome. Thus the structure of teaching competence embraces three dimensions which are as follows.

i) Knowledge (Teachers cognitive abilities).

ii) Performance (Teachers behaviour and teaching skills).

iii) Consequence (Pupils learning outcomes).
Knowledge competencies represent the teachers professional knowledge and specify the cognitive understandings the teacher is expected to demonstrate. Performance competencies specify teaching process the teacher is expected to demonstrate. Consequence competencies specify pupil behaviour that are viewed as evidence of teaching effectiveness. Knowledge competences is considered to be the base in order to attain performance competencies. Both together are essential in turn to attain consequence competencies.

Science teaching competencies thus means the degree of perfection or the optimum level of efficiency and productivity on the part of a teacher teaching science. It also refers to the level of height of maturity and learning a teacher acquires on the basis of personal knowledge, training and experience gained as the teacher grows.

1.2.2 Competency based teacher education

In order to visualize the impact of teacher education programmes on the competence of teachers, some of the teacher education programmes are discussed hereunder.

For deriving the specific competencies two stage process job analysis and skill analysis are used (DACUM, Canada, 1983). The prime use of these competencies is to guide the design of training. For example, a strong movement in North America in 1970s adopted competency based teacher education (CBTE) and competency testing in schools as a part of this new movement. Considerable emphasis was placed on individualized ‘mastery learning’ approaches to the delivery of teacher education programme, which required specific behavioural objectives. These in turn were to be derived from competencies specifying the role requirements of teachers.

Competencies of the kind used in the competency based training forms micro competencies and competencies of the more generic kind are macro competencies. So, for a teacher whose position in the professional ladder lies at bottom of the hierarchy micro competencies is not of less importance as well the macro competencies.

According to Elkin’s model (as cited in Curr-Sounders, 1993) people develop many of their job competencies in the post, that is after they have been appointed
which help in long-term career employment in the job. But once this core has been achieved the individuals may aspire to further growth by gaining a set of developmental competencies. While not irrelevant to the current job, these developmental competencies may be an important, if not essential factor in gaining promotion to a more senior post. So, a science teacher along with his core competence on teaching skills may seek or aspire the innovative methods of teaching, or enrich his/her science content in the specialized areas modern to develop his/her competence on the field of science teaching.

In Indian context, an effort is made to conceptualize competency based in-service teacher education as a drive for improving quality of school education. (NCERT, 1998) In the document titled “Competency based and commitment oriented teacher education for quality school Education” ten competency categories in teacher education had been identified. Among them the conceptual competencies, content competences, transactional competencies and evaluation competencies were found to be very relevant to the present study. Some of the abilities referred to in the context of these competencies are as follows.

(1) Conceptual competencies: Teacher understand the general meaning of learning outcomes, competency, competency statements and cluster of competencies; comprehend the difference between specifications of behavioural objectives and competency statements; understand the utility of criterion-referenced test and norm referenced test without specific reference to a subject. (2) Content competencies: Teacher identify facts, concepts, principles and theories in a school subject; comprehend relationships among facts, concepts, principles and theories constituting the structure with reference to a particular school subject. Teacher identify new developments in the subject and classify them in terms of structure of the subject. (3) Transactional competencies: Teacher plan the use of textbook and other learning material in the competency based teaching learning process; engage pupils in group-learning, peer-learning, individual learning and in using the occasion for close supervision. (4) Evaluation competencies: Teacher understands the concept and importance of evaluation in the process of implementation of minimum levels of
learning; plan yearly/monthly units of programs; prepare a blue print for construction of test; analyze and interpret test data applying suitable method; identify students needing remedial teaching programs. The first three of above competencies are related to pedagogy, subject matter and combination of these two respectively. Fourth one is a part of first competency.

1.2.2.1 Pre-service to in-service linkage

For many tasks, neither broad scope nor special expertise is expected. This is what the real status of novice teachers who are recruited for classroom teaching just after completion of a B.Ed. or D.Ed. course. Hence they will form part of the agreed core of their appropriate professional qualification. For some tasks and roles, quality is of considerable significance. So, there will be limited interest in a professional profile which gives no indication of quality in these areas. In many or in almost all occupations nature of professional work is changing quite rapidly not only as a result of technical change but also as a result of social change and institutional change. Constant redefinition of teaching as well as role of teacher in school education system forms one such example. Professionals will be changing the scope of their competence, through becoming more specialist, through moving into newly developing areas of professional work, or through taking on educational roles; and they will also be continuously developing the quality of their work in number of areas, beyond the level of competence to one of the proficiency. All these arguments are equally valid for those in-service teachers working for teaching profession. Moreover, how a competence base of a new entrant with preservice teaching qualification differs at all with that of an in-service teacher is more important. The former as a newly qualified professional have knowledge and skills relevant to his tasks at the point of his qualification. But to be minimally competent the opportunity to learn in work settings which can be made available only through undergoing a teaching experience for certain period is very much essential. So, duration of two years is estimated and fixed as minimum teaching experience for any teacher to be referred as ‘in-service teacher’. Again a very special characteristic of teaching profession is that, as a qualified worker, teacher is expected to perform his prime role
with virtually no supervision. Thus, competence can thus happens to mean anything from ready-to-start-work based learning to being highly reliable and proficient.

Now, therefore, one can think of two grounds to assign the levels of science teaching competencies possessed by teachers. The first aspect is to find answer for the question, in real situation what should be the levels of potential abilities of any science graduate (B.Sc.) just after undergoing a university level preservice teacher training (B.Ed.) course? Second aspect is to determine what is the level of their performance in delivering science lessons in actual classrooms after acquiring this qualification followed by a novitiate period of opportunity to learn and practice their intellectual competence?

So, in connection with the effort to develop a meaningful compact structure for science teaching competencies the discussion is carried out in two sections. Firstly, the pre-service education course (B.Ed.) structure which prescribes a basis for the question “What it should be?” This is followed by a discussion on the status science teaching and present in-service teacher education course which attempts to answer “what it is really now?” The pro-active approach adopted through an experimental treatment in the present study forms an attempt to answer “how it could be improved further?”

1.2.3 Science Teaching Competencies in Pre-Service Teacher Education Course

A review into course structure and objectives as described in documents - Teacher Education Curriculum a Framework (NCERT, 1975), and the discussion document of curriculum framework for teacher education (NCTE, 1998), it is understood that a science teacher is expected to have a knowledge base in three areas and an attitude favouring to the subject. This can be summarized as follows.

(1) Knowledge of psychological principles of teaching learning in general.

Knowledge of general teaching skills, education technology and laboratory skills of science. Knowledge of methodology and educational process related to science (The general pedagogical skill).

(2) Knowledge of science that he/she is expected to teach and knowledge of content analysis (The subject matter area).
(3) Ability to understand and apply all these knowledge in classroom teaching while transacting the curriculum (Pedagogical content knowledge).

(4) Developing a favourable attitude towards the subject science and towards the teaching of the subject science (The teachers attitude toward science teaching).

All the four areas identified forms the component forms of general structure of science teaching competencies. Resolution of these areas into deeper level is possible which lead to identification of specific competencies. This can be accomplished by examining the detailed content structure syllabus of B.Ed. course of any university or any other apex body, and developing a compact structure of expected level science competencies.

Again, teachers are expected to apply practically their knowledge base in performance form in the actual classroom situation. This forms the performance science teaching competencies, which can be evaluated through classroom observation. The observation schedules used for evaluating practice teaching provides the extensive criteria for performance competencies.

But in pre-service training there is no provision for evaluating teachers on the basis of any students effects such as learning outcome. This necessitates a ground for evaluating teachers’ performance competence through students’ learning outcomes.

**1.2.4 Desired Level of Science Teaching Competencies**

A profile of Science Teaching competencies can be described on following dimensional composition and component categories.

(a) Knowledge based science teaching competencies: (K-STC)

This involves a cognitive dimension of what knowledge aspects related to science is acquired by a science teacher. It includes three components that can be evaluated by paper-pencil tests. The components are as follows.

**Subject matter knowledge (SMK)**

These competencies are related to teachers’ knowledge of all science content as prescribed in the syllabus and in the textbook of eighth grade of Karnataka State with some additional resource knowledge on latest advances and progress of science as an extension of content knowledge.
General Pedagogical Knowledge (GPK)

These competencies are derived from teaching processes-the knowledge of pedagogy. It includes the knowledge of the nature and structure of science processes and the method of science-content categories-fields of science-content analysis-planning-methodology-materials-skills-evaluation related to teaching science.

Pedagogical Content Knowledge (PCK)

These competencies includes the cognitive activity that requires the transformation of teachers, knowledge from diverse domains such as subject matter knowledge, general pedagogical knowledge and the knowledge of context.

(b) Performance based science teaching competencies (P-STC)

These competencies deal with classroom processes, which are visualized by the on-going teacher behaviour as performed in actual classroom. It mainly deals with teaching skills applied specially to the context of teaching scientific facts, concepts, generalization, principles and so on.

(c) Consequence based science teaching competencies (C-STC)

These competencies refer to pupils outcomes produced by the teachers’ proper use of an array of knowledge and performance competencies. Achievement in science is one of the important product outcome which can be treated as a measure of impact of sciences teaching competencies over students learning. More details of extending these components into science teaching competencies and their sub-level categories are discussed in chapter three.

1.3 IN-SERVICE TEACHER TRAINING PROGRAMME RELATED TO SCIENCE EDUCATION

After exploring the status of science teaching and the desired structure of science teaching competencies, it is worth thinking on attempts and means to improve science teacher’s competencies and science teaching on the whole.

As already discussed the status of science teaching in schools is not satisfactory. The research efforts to improve over the situation are just limited to the formulation or revision of curriculum and objectives rather than any extended study on classroom transactions. The research attempts directed in to the area of classroom
teaching performance were not found to be comprehensive. It is found that the competencies referred were all very general in nature, with no subject specific references. There are hardly any studies conducted on the development of teachers’ competence in teaching of science and evaluative measures to assess the competencies. While much of the literature, particularly in the area of competency based training, which dealt with the nature of teacher competence rarely has any discussion focused on the procedures needed to translate behavioural concepts and variables into competencies.

It is seen that in a pre-service training course such as B.Ed., because of its brisk nature and short duration of time, there is every possibility that the teachers gain teaching skills to a moderate level. In the in-service career of teachers, there remains the chances of either getting erosion of these pedagogical skills acquired resulting in teacher freezing, or there may be gaps to be filled up for effective development of these skills to the fullest extent. Only need-based in-service training can help the teachers to come out of these types of stagnant situations.

Referring to the literature on job training, it is understood that performance objectives and the skill analysis are the basic requirements to increase the quality of performance. These are carried out to match the competencies in the current general levels of skills and abilities possessed by employees (Fowler, 1991). So, it describes what skills an employee needs to acquire competence in a particular job. In the effort to identify skills and competency requirements characteristics of people as required by the job should be included. This element indicates nothing but the presage variables of teachers. On the basis of these background informations a discussion on the contemporary practices of conducting in-service training follows.

1.3.1 Status of In-service Teacher Training

The methods adopted for training in general become an important issue to be considered. It should be cost-worthy and time-worthy. The training methods in general may be ‘on-the-job’ or ‘off-the-job’ or combination of both. On-the-job training is probably the most common approach of training and can range from relatively unsophisticated ‘observe and copy’ methods to highly structural courses
built up in the form of workshop or office practice. Off-the-job training is sometimes necessary to get people away from the work environment to a place where in the frustrations and bustle of work are eliminated.

Whatever be the methods employed, nothing wrong to mean, but how they are utilized by the trainer and the learner is more important. That is, making the appropriate match between the training requirements of the employees and the training methods available is the key issue. Interactive leaning techniques—workshops, case studies, role plays, simulations, interactive computer learning packages, problem solving etc can be used for training sessions.

Responsibility for delivery of training also forms one of the decisive criteria related quality of training. Usually there are many large organization rested very much with specialist departments. For example, in Karnataka State Colleges of Teacher Education are the regional organization authorized by state government to impart all in-service teacher education for secondary school teachers covered under a jurisdiction fixed for purpose. But main criticism against such establishments are —

- Too rigid to respond to the changing needs of the organization.
- Being too much of an administrative expense.
- Lost contact with the changing skills and needs at the work place.
- Highly bureaucratic in nature.
- Provide training on theory with no practicals.
- Provide only ‘off-the-job’ training which do not match with ‘on the-job’ needs.

Evaluation and monitoring of training is one of the most important but often neglected part of training process. It can be seen as simplistic and at the same time it is really much complicated. It is relatively easy to evaluate a formal ‘off-the-job’ course; much ‘on-the-job’ training often takes place in an informal way which is usually subjective and open to wide interpretation (Holden, 1991). Questionnaires (Feedback-forms), Tests, Projects, structured exercise, Interviews, observation, participation and Discussion etc can be used in combination.

Any training prescriptions can appear too simplistic particularly in a text book or in a training package which has limited space to provide with. The reality of creating training strategies is much more complex; frustration and failure to achieve
objectives is very common. Another reality is that there is no clear evidence connecting training to organizational efficiency and profitability, although there is a widespread belief that this is the case.

A review of the present status of in-service teacher education on the basis of HRD principles discussed above leads to find a desperately wide gap. For example, every year lot of money is spent on providing training to secondary school teachers. Particulary in case of Karnataka the training programmes are designed and conducted on the basis of yearly allotment of funds to Colleges of Teacher Education. So, the need, purpose and prospects of training programme entirely goes with the interest of spending this money with in the deadline dates of particular academic year.

Thus, while designing in-service courses, naturally little effort is taken to know the present need and level of knowledge of the target group. As a result, teachers are not selecting the in-service programme, but the in-service programme (organizers) selects the teachers !. The overall interest is to make a group of teachers to sit and listen to some lecturers for certain number of days. Everything in the training is provided free of cost including food and traveling expenses. The training grants or funds are neatly spent and accounts are settled on the basis of standing expenditure guidelines. Many times teachers simply participate; enjoy the passive listening to some lectures, mostly on science content provided by post-graduate college teachers. Resources on pedagogical skills which help for classroom transaction of these content rarely finds any place in these training agenda. The training programmes are converted as off-the-campus relaxing sessions. In the present situation, teachers are intended to realize that there is no compulsion on them to attend any in-service programme because they do not find any incentive. They do not feel like attending such programme nor feel any need to learn anything in the programme, as they are aware of the reality that it will never lead to any promotions.

In most of the in-service programme of secondary school teachers, instructional materials either not at all provided or if provided they are not developed well. There seems to be little practice of providing the course structure, time schedule and literatures related to sessional work. Resource persons are chosen hurriedly at last
moment. So they come with little preparation and with no prepared materials. Mis-coordination or missing coordination between different resource persons occurs frequently. And there may be missing linkage between the theme fixed and transactions delivered in the training sessions. Hardly there would be any effort to evaluate the effectiveness of in-service programme. So, the in-service programme become ineffective because of defective planning, relevancy, design, preparation of training materials, resource persons, method of transaction or execution, evaluation and revision etc.

For an effective in service training programme, we can follow the HRD plan as described below.

- Analyze the training requirement for effective work performance in organisational functions and jobs.
- Analyze the existing qualities and training needs of current employees.
- Devise an HRD plan which fills the gap between organisational requirements and the present skills and knowledge of employees.
- Decide on the appropriate training and development methods to be used for individual and groups.
- Decide who is to have responsibility for the plan and its various parts.
- Implement the plan and monitor; and evaluate its progress. (Holden, 1991)

In order to improve the effectiveness of in-service training, the following principle may be adopted as standards:

- The teachers should volunteer themselves by freely choosing the in-service course as a felt need.
- And consequently teachers must be prepared to attend such courses (by not expecting any financial benefits) for their own benefits, with self interest.
- The in-service course arranged must convince the participant teachers as helpful, in a way to improve their overall teaching abilities by enriching course content on new innovative fields of knowledge.
- The course must be designed well with supporting literature developed preferably in the form of modules.
Implementation and execution of course must be based on a comprehensive action plan (system plan) suitable in all respects to the working conditions of teachers.

Agency which organize the in-service-programme should be competent to deliver the course.

Such agency should have a baseline data which determine the deficiencies in the subject knowledge and professional competence of the in-service teachers which helps to decide course content.

Evaluation and feedback activities are to be carried out at the end of each stage.

1.3.2 In-Service Programme Related to Science Teaching

As already discussed, teachers professional development is a continuum. The development process starts at the entry when a teacher is inducted to the service, after acquiring the required preservice training, and it continues throughout the career in the form of regular in-service development. This in-service development is a natural consequence of the results and experiences and reflective thoughts generated from these experiences. Following rationale is suggested for in-service teacher programme which is aimed at improvement of teacher quality (Anand, 1999):

- To keep attention focused on the need of improved quality of educational outcomes through better performance.
- To maintain an environment that would facilitate quality learning in school through teachers’ own commitment.
- To enable teachers to develop the new competencies which they need to acquire in their career options.
- To develop the concept of teaching as a profession, offering career-long challenges, satisfaction and rewards.
- To maintain the motivation and enthusiasm of teachers and other functionaries.

Some more needs can be identified for designing in-service education for teachers (Das & Jangira, 1989) which are listed below.

- For filling in deficiencies in knowledge of teachers in the subject areas they teach:

The scope of in-service teacher education in first place should have an objective for filling deficiencies in teachers’ knowledge and understanding of
subject content, which are required to explain the concepts of the school science subject.

- For acquainting teachers with new innovations and research findings in education as well as changes in educational policy:

  In teaching, both the parts of methodology – general methods of teaching which are common to all school subjects and subject specific methods or techniques – are to be included as competence base. General methods of teaching are skills relating to introducing a topic, narration, putting probing and/or thought provoking questions, generalizing, summarizing, illustrating with examples, writing on the black-board, using audio-visual aids, applying general principles in particular cases, closing a lesson etc. Subject specific methods for science may be conducting a laboratory lesson, demonstration of all the experiments related to contents etc. Science teachers must be oriented on innovative approaches and methods of teaching. Hence teachers have to realize that knowledge is constructed, and does not exist independent of method of science. They should be oriented into the process of science, starting from small exercise of observing, communicating, classifying etc. and extending up to the development of scientific attitude and values.

- For increasing the knowledge of teachers in special areas of education such as educational technology, use of computers in education, integrated education of the handicapped etc;

  Use of audio-visual aids, electronic media and educational technology should be part and parcel of teaching-learning activity. Instructional designing should be a strategy-exercise by adopting content and task analysis, the process of translating content in terms of instructional objectives and the expected learning outcomes.

- For preparing teachers for administrative/supervisory job.

  Science teachers are expected to have an active role in setting up a laboratory with modern facilities and design, to organize science activities like science exhibition, science fair, science examinations and evaluatory works, science purchase and maintainance of stock records and registers, etc.
So, the scope of in-service teacher education may vary from providing knowledge on wide and extensive basis on everything related to the field of education to narrow and intensive basis on developing single ability say practicing concept attainment (teaching) or conducting a school examination (administration).

Any literature on training should have a wide scope to develop competencies in all these areas.

Transactional mode adopted in training can be as simple as giving information about the topic. It can be followed by a demonstration by the resource person. Then the teachers are to be provided with the opportunity to practice in small groups. Immediate feedback is to be given on this group work. Finally, a supervision is needed to provide further suggestions, when the teachers go back and implement these new practices. Science teachers’ competencies both in knowledge and performance fields are to be measured and analysed. Such an in-service programme with comprehensive design and well planned strategy for implementing, could only succeed in developing the science teaching competencies.

1.4 RATIONALE NEED AND SIGNIFICANCE OF THE STUDY

So, the gist of preceding discussion is that the science occupies a prime status in school curriculum. Science has got a profound impact on technological development and the consequent well being of human life on the earth. So, a continuous effort to provide good science education to the new generation is found across nations all over the world including India. But the status of science teaching-learning many a times subject to criticism. Lack of infrastructure, equipments, laboratory facilities are just the question of spending money out of state fund. But there is a bigger issue. In Indian situation only, we can find system with highly updated objectives, curriculum and teachers who have undergone good preservice training fail to deliver the goods. For instance, the students’ achievement in science in formal certification examinations in many states (like the results of Secondary School Leaving Certificate Examination of Karnataka State) are always found poor. The aspirants who join pure science courses is declining year by year. The research and development (R&D) organisation on pure science find it difficult to get good science
graduates to be trained as future scientists. In schools, the newly recruited teachers enter into the profession of science teacher with sufficient pedagogical background. But when they start teaching at schools, availability of good laboratory, teaching aids, science books, etc. became irrelevant. Because the practices in schools make teachers to follow the dominating system of examination-centered-rote-learning. So, it is the quality of classroom teaching practices are responsible for the stagnant performances and results in science, that we observe today. The investigator who served in the field of secondary education in various positions such as Science Teacher, Head master, Teacher Educator, Education Coordinator for a long period of two decades experienced the real burning problems in science education at primary and secondary school levels. And all these drawbacks are rightly pointed out by education commissions, reviews and research reports. In science classes only the lecturing is dominant. Pupil listen and never question. They read the readymade (teacher made) question-answer write-up notes. Rote learning of answers to some listed set of questions on textual matter is the main activity both at school and at home (homework). Demonstrations are done rarely but fully in teacher managed fashion. Written examinations scores (marks) – ranking becomes the overall evaluation process. Teachers have no scope to employ any renewed practices of methods on teaching and assessment work nor they can take student beyond textbooks or beyond the territory of classroom. These teachers attend very few in-service training programmes. But most of the time the trainings are on content enrichment, rarely deal with pedagogical aspects. Teachers attend these training, many a time, out of compulsion or just to avail some relaxation. The organisations which arrange the training programme were more interested in functioning, accounting and logistic aspects, rather than any academic impacts on teachers through these trainings.

All these first hand experiences and observations forced the investigator to take up a research project to sensitize the system of schools by providing a need-based training programme thereby to equip the teachers with improved science teaching competence and better teaching practices to influence the learning levels of their students.
Hence, building as appraisal system based on science teaching competencies and developing modular instructional package on these competencies (which can be effectively used to organize in-service training strategy) all-together lead to a descriptive-correlational-experimental research loop. This aspect forms the prime rationale of the present study.

But building an appraisal system based on teaching/teacher competencies is a developmental task. Teaching behaviours are to be translated into variable in order to identify and validate proficiency levels.

So, first of all there is a need to develop a profile of science teaching competencies based on theoretical principles keeping in mind that the concept of teaching competence lacks clarity and agreement, and also lacks the quality of a variable, making its measurement a difficult task. Again, this process is both multifaceted and longitudinal. Scope and range of proficiency level for such competencies can be outlined on the basis of theoretical cum empirical process. Prescriptions are to be drawn from review of theoretical principles related to three fields of thinking (a) Teaching as a professional competence, (b) Science as school subject characterized by its own nature and structural aspects, (c) Pedagogical principles of science teaching as outlined in pre-service teacher training courses. Structure of such a set of science teaching competencies with reference to curriculum of a particular grade, say eighth standard science can be expressed in three dimensional form: (a) Knowledge based competencies, (b) Performance based competencies and (c) Consequence based competencies. This draft of science teaching competencies can be taken to the field and analyzed against the directly observed classroom practices of in-service teachers of a lab-area. This empirical touch though looks trivial, offers deep impact and helps to transform the draft into a practically feasible compact format. The scope and range of the desired level of science teaching competencies are screened, delimited and focused more on the observed as well as need-based areas of science teaching in relation to the prevalent status of teaching among the schools of lab area.
A classical model for studying the teaching in natural setting of classrooms can be used for the strategic research effort directed to improve the observed science teaching competencies in terms of the descriptive – Correlational-Experimental loop. This model contains at least three elements.

(i) Development of procedures for describing teaching in a qualitative manner;
(ii) Co-relational studies in which the descriptive variables are related to measures of student growth;
(iii) Experimental studies in which the significant variables obtained in the correlational studies are tested in a more controlled situation.

These steps are not isolated from one another and moreover there are three overlapping contexts within which this step wise instructional research takes place.

First among them is classroom focused research. This is the study of classroom teaching as it exists, mostly which relates instructional activities and student growth. Flanders (1969), Nuthall (1971) studies are examples for classroom focused research. Nuthall tried to develop an experimental method which is responsive to the full complexity of the classroom situation, and which will provide the kind of data which reflects the important characteristics of contemporary classroom teaching.

Second type is the Teaching-Skills Approach. Here the focus is on training of teachers in specific skills. Investigators focus upon specific aspect of teacher’s task rather than on all parts of teaching at once (Gage, 1963). For example, (Mitz, 1971) developed teacher training materials on how to explain. Third is the Curriculum Materials approach. In this approach curriculum model which is a set of instructional materials and instructions for their use were packed for dissemination. For example, studies by Rosenshine (1971), Montessori (Evans, as cited in Travers, 1971), etc. These materials are quite different from the usual practice of providing a teacher with only a set of books, a syllabus and vague objectives.

Particularly, the research loop endorsed by Rosenshine, which upto certain level is found to be highly relevant to the present study. It consists of: (i) Training teachers to use a certain package materials. (ii) Using observational systems to
describe instructional activities on variables considered important for the implementation of specific programme and also on variables considered to have general educational importance. (iii) Studying the relationship between instructional activities and student growth (on a variety of outcomes) within those groups of teachers who are supposed to be using the experimental treatment. (iv) Changing training procedures and/or materials on the basis of these studies and (v) Conducting new studies to determine the effects of the modifications and to determine the new relationship between instructional activities and student growth (Rosenshine and Frust 1971). In the present study only the first three aspects the cyclic process are adopted.

Now, the structural model for improving the existing level of science teaching competencies, representing briefly the rationale of study can be described as follows.

**Figure 1.2: Schematic structural model adopted for the study**

The present study draws its significance from the following features of research work. The research study –

- Attempts to assign a compact structure in all inclusive way for science teaching competencies of teaching science of a particular grade that is eighth standard science.
● Produces a comprehensive literature in the form of modular package that can be used for the benefit of all secondary school science teachers while organizing any in-service training or simply as a self instructional material.

● As far as possible extends to cover many variables, established interactions and correlations between these variables out of four sub groups of variables identified in Dunkin and Biddle model (1974) for research in teaching: (a) Presage variables, (b) Process variable, (c) Product variables. Also proper measures are taken to consider the secondary effect of fourth group of variables, (d) Context variables, by considering these as background variables.

● Accounts for science teachers’ teaching effectiveness, in turn bring out students learning which is the prime goal of imparting science education. And hence step to improve teacher effectiveness has a direct bearing on enhancement of quality of science education.

● Gives importance to actual classroom observation which is considered as powerful means to study teaching. Research on teaching has for long time been conducted by standing outside the classroom and therefore actual classroom behavior of teachers has been sidetracked. ‘We must begin to examine what teachers do, not what teachers are’ (Bloom, 1968). Insights into the teaching process and the interaction of its variables can probably best be gained by observational techniques (Avalos and Haddad 1981).

So all the preceding discussions lead to the emergence of a research problem as stated below.

1.5 STATEMENT OF THE PROBLEM

To Study the Effectiveness of Instructional Package in Science Teaching Competencies over Teachers Performance and their Impact over Students Achievement and Process Skills in Science.

1.6 OPERATIONAL DEFINITIONS OF THE TERMS

The key terms used in the above statement of problem of the study have following operational meaning.
(i) Instructional package in science teaching competencies

“Instructional package in science teaching competencies” simply stands for the training material used in the context of specially designed in-service training, which was the main part of interventional program adopted in the present study. Hence this interventional program was called by an abbreviated form IPIT(Instructional Package based In-services Training) program. This instructional package is a self-instructional package based on modular approach. The transactional mode suggested in these modules are mainly in the form of expert lectures, discussions, groupworks, exercises to stimulate thinking, assignments in the form of library reference, projects, etc. The package is a set of eight models developed on eight important areas of science teaching competencies.

(ii) Science teaching competencies

“Science teaching competencies” generally stands for a set of knowledge, abilities, skills, attitudes and related teacher characteristics the teacher possesses and brings to the teaching situation. They are measured in terms of cogitative and performance dimensions and also on the basis of pupil outcome. In the present study science teaching competencies were defined by a set of generic statements over different domains of science teaching. These competencies were assigned with an assessment criteria based on three dimensional aspects such as knowledge based – performance based – consequence based competencies. The knowledge based science teaching competencies were assessed again on the basis of three aspects – Subject matter (SMK), General Pedagogy (GPK) and Pedagogical Content (PCK). Formulation of science teaching competencies in this way proceeds and guides the development of Instructional Package.

(iii) Teachers performance

“Teachers performance” refers to teachers’ performance (a) on knowledge based science teaching competencies test and (b) in practical ongoing classroom teaching of science.

(iv) Students achievement

“Achievement” in general sense refers to the proficiency of performance on a given skill or a body of knowledge. The term is used more generally to describe
performance in the subjects of the curriculum (International Directory of Education, 1977). In the present study it refers to the performance of the students in an achievement test developed on the content of eighth standard science.

(v) **Science process skills**

Science process skills stands for those well defined specific intellectual skills used by all scientists, identified by and listed by projects such as: Science – A Process Approach SAPA (1963-67). In science education there are many such well defined thinking skills which are categorised as basic and integrated process skills. Among these, the investigator selected six basic and one integrated process skills which are found suitable for the present context: (i) observing, (ii) communicating, (iii) measuring, (iv) classifying, (v) inferring, (vi) predicting and (vii) experimenting.

1.7 **VARIABLES OF THE STUDY**

The following seven variables were selected to conduct the present study.

(a) **Independent Variable**

(1) Instructional Package based In-service Training (IPIT) programme: The instructional package developed on science teaching competencies is used in the in-service training programme to study its effect.

(b) **Dependent Variables**

Teacher variables (direct effects)

(1) Science Teaching competencies 1- Knowledge based
(2) Science Teaching Competencies 2- Performance based
(3) Attitudes towards science teaching

Pupil variables (consequence effects)

(4) Achievement in (eighth) science: cognitive domain and drawing skill
(5) Science Process skills
(6) Attitude towards Science

Meaning and definition of these variables will be discussed in later sections on tools.

(c) **Secondary/background variables**

Following background variables related to teachers and students were also chosen for the study.
Teacher related variables
(1) Gender
(2) School locale
(3) School type
(4) Age
(5) Professional experience
(6) Previous in-service training

Student related variables
(1) Gender
(2) School locale
(3) School type

1.8 OBJECTIVES OF THE STUDY
1. To identify, the various dimensions and aspects of science teaching competencies required for teaching science at secondary school level, on basis of suitable assessment criteria
2. To develop an Instructional Package on science teaching competencies with an intension of providing in-service training to secondary school science teachers.
3. To conduct an Instructional Package based In-service Training (IPIT) programme for a group of secondary school science teachers by using the Instructional Package with an objective of developing their science teaching competencies.
4. To study the effectiveness of the Instructional Package based In-service Training (IPIT) program on (a) Knowledge and classroom performance based science teaching competencies and (b) Attitude towards science teaching of science teachers.
5. To study the influence of teacher factors such as Gender, Age, Professional experience and previous in-service teacher training experiences on teachers teaching competencies in science and also on teachers attitudes towards science teaching.
6. To study the influence of school factors such as locale and school type over the teachers competencies and teachers attitude towards science.
7. To study the impact of the in-service training of the teachers in science competencies over the consequence effects on students (a) Achievement in science, (b) Science process skills and (c) Attitude towards science
8. To study the influence of school factors such as locale and school type over students achievement in science, science process skill and attitude towards science.
9. To study the relationship between science teaching competencies of teachers and the students’ achievement and process skills in science as consequence effect.

1.9 MAIN HYPOTHESES OF THE STUDY

H₁ There is a significant difference between Knowledge based Science Teaching Competencies (KSTC) of teachers measured before and after the implementation of the Instructional Package based In-service Training (IPIT) programme.

H₂ There is a significant difference between Performance based Science Teaching Competencies (PSTC) of teachers measured before and after the implementation of the instructional package based in service training (IPIT) programme.

H₃ There is a significant difference between Teachers Attitude towards Science Teaching (TAST) measured before and after the implementation of Instructional Package based In-service Training (IPIT) programme.

H₄ There is a significant difference in students achievement in science as an effect of teachers competencies in teachings science due to Instructional Package based In-service Training (IPIT) program.

H₅ There is a significant difference in students science process skills as an effect of teachers competencies in teachings science due to Instructional Package based In-service Training (IPIT) program.

H₆ There is a significant difference in students attitudes towards science as an effect of teachers competencies in teachings science due to Instructional Package based In-service Training (IPIT) program.
H₇ There is a significant positive relationship between test scores of knowledge, performance and attitudinal dimensions of science teaching competencies of experimental group teachers, both in pre-test and post-test.

H₈ There is a significant positive relationship between test scores of achievement, science process skills and attitudinal dimensions of consequence science teaching competencies related to experimental group students, both in pre-test and post-test.

H₉ There is a significant positive relationship between classwise changes in teachers’ science teaching competencies and changes in students’ achievement and process skills in science, as a consequence effect of IPIT programme.

1.10 ASSUMPTIONS OF THE STUDY

The main assumption of the study is that all the abilities or capabilities extending up to the conceptual meaning of teaching effectiveness and the functional attributes related to teaching of science subject can be defined by a structural pattern. And such a structure can be developed by evolving the meaning of teaching, essentially as a function of professional competence as described by the management theories and also on the basis of core competencies given in university level course structures of pre-service teacher education.

Again, Science teaching competencies with appropriately formatted structure could be characterized like a variable and as a situation or context free stable characteristics of a teacher.

Science topics of eighth grade science can provide full scope to practice teaching skills and competencies as desired and outlined in the structure of science teaching competencies.

The experimental treatment programme envisaged is compatible with the prevailing secondary school system and such that it can be smoothly introduced as an intervention programme in an acceptable way to the teachers, students and school administration.

Science process skills can be developed both in content free as well as content bound situations.