2.0 INTRODUCTION

A review of literature and research studies related to the present study is presented in this chapter. The presentation has an objective to justify the rationale of study and thus drawing empirical support for the study. Since the review provides an overall historical perspective, together with different modes of approach adopted over a progressive deviations and departures due to modified and renewed thoughts, serves as a basis to structurize a design for the study with proper assumptions.

The chapter includes the literature and the research studies related to (i) status of science teaching, (ii) science teaching competencies, (iii) teaching effectiveness, (iv) effect of science teaching on pupil’s achievement, (v) understanding science, science processes and (vi) classroom practices.

Even though the present study provides scope to review innumerable studies related to many aspects of teaching and learning of science, the investigator restricted the review to cover only those studies which provide specific bearing with respect to either of the purposes such as theoretical conceptualization, methods, samples, variables, and tools.

2.1 STUDIES RELATED TO STATUS OF SCIENCE TEACHING AT SECONDARY LEVEL IN INDIA

Science has been visualized as a great human enterprise. Gagne (1965) and Carin and Sund (1970) described the structure of science in terms of its intellectual effect, such as body of knowledge, process of acquiring knowledge, a set of attitudes, a way of systematized thinking etc; apart from its materialistic effect of producing good food, clothing, housing, medicines and other human luxury and life. Hence science finds an important place in ever growing school curriculum. Accordingly, the teaching of science has been an ever challenging profession for science teachers
particularly since last fifty years, when science education came to be recognized around the world as an independent field of research.

While reviewing the research studies related to science education that were taken up during the last few decades, it was realized that these studies never focused on any single theme but fully scattered over. Moreover, the studies pointed out more defects than effects. Some survey studies pointed out to the problem of laboratory facilities, insufficient teacher training, weak curriculum and poor course structures.

Veerappa (1958), in his comprehensive study on status and trends in science education covering from primary to university level, pointed out that due to want of laboratory facilities and due to the lack of well trained science teachers, science education in India was not on proper footing. Patole (1967) also pinpointed to the lack of science apparatus, science rooms and qualified teachers as the existing weaknesses in teaching of science in rural primary schools of Kolhapur district. Swarnamma (1978), in a state wide survey, observed that the achievement level of seventh standard pupils in biology was not quite satisfactory because teachers did not gain adequate mastery even in case of simple skills and experimentation. Also, it was found that the teachers, in general, failed to develop scientific attitude among pupils. Gupta (1978), in his report on science teaching programme in Hoshangabad district, remarked that the state of science teaching in our country had been highly unsatisfactory. Rajput, Gupta and Vaidya (1978) conducted two studies: (i) In a survey on opinion of science teachers with respect to the objectives of laboratory work, the following objectives were outlined: to verify facts taught in theory classes; to create interest in science; to prepare good scientists for the country, to develop skill of handling apparatus/equipment; to observe and critically think about the results; to develop the habit of reasoning, to avoid memorizing the subject, and so on. More interesting is to note that although these lofty objectives were perceived by the science teachers, the major unwritten goal of laboratory work was, however, to prepare students for practical examinations held externally. (ii) In a survey conducted in the western region of India on status of laboratory facilities available in the secondary schools, some of the problems faced by teachers were listed: like lack of
free time for practical work, poor quality of apparatus, lack of necessary skill to conduct the experiment, poor human and physical resources etc. Krishnan (1981), in a critical study of the secondary school science curriculum of the states of Kerala and Tamil Nadu, found that the curriculum of Kerala was lacking teacher’s handbook and was weak in providing experiences for developing general manipulative skills. The curriculum of Tamil Nadu was found weak in laboratory work, audio visual aids and in provision of textbooks. Siddique (as cited in NCERT, 1991), after summarizing various curriculum programmes commented that in India, science teaching had yet to take a new impetus and in classrooms one could find that science was either reading or telling and in very few cases science was doing. Sharma (1984), in his study, surveyed growth and development of science education in Bihar and found that there was a need for modernizing and strengthening administration in the field of science education, especially with respect to aims, curriculum, text book, techniques, materials and equipments.

Some of the studies also pointed out the domination of lecture method in science classrooms. Maddu (1978) found that most of the biology teachers preferred lecture demonstration method. Ragini (as cited in NCERT, 1991) studied the classroom behaviour of science teachers by using science teaching observation schedule (STOS) developed by Eggleston, which revealed that teacher were intended to impart more information, ask questions and direct the students for fact finding rather than to involve students in science activities. Hence the teachers were more didactic and not heuristic in their classroom behaviours.

Lack of stress on science process were of concern in few studies. Brown (1966), in his study on the list of objectives of science teaching in India, expressed satisfaction that the objectives revealed a concern of science educators for developing an adequate understanding of processes of science in students. But no further development in this line during the subsequent years was identified by Dorasami (1970), Bhatnagar (1970), Pritham Singh (1971) (as cited in Buch,1979), who pointed out the weakness of teaching science due to lack of process oriented conceptual goals among the objectives fixed for science of teaching. Kumar V.S. (1992) revealed that
development of scientific attitudes depend on one’s perception of science teaching
and nature of learning experience. So, suitable classroom setting and nature of
learning experience are emphasized for developing of nature of science and science
related attitudes among students.

But at the same time, studies outside India showed more concern on student
centered classroom and learning techniques. Anderson (1987) summarized the results
of an international level study of classrooms conducted in nine countries. He found
that three primary type of activities occurred to a greater or lesser extent in the
classrooms in all participating countries: (1) teachers talk “at” or “with” their
students, (2) students work on assignments at the desks or at laboratory tables, (3) and
teachers engage in a set of general classroom management activities such as taking
attendance or distributing and collecting papers etc. Peter, Akin Sola, Okebukola,
Johson and Johson (as cited in Anderson, 1987) proved that co-operative and
competitive learning techniques exert note-worthy effects on a variety of cognitive
and social effective variable. Cooperative-competitive learning techniques have
greater positive effects on student’s performance in science when compared with
traditional approaches. Hankoos and Penik (as cited in Anderson, 1987) reported that
the discovery classroom climate facilitated better gains in student’s knowledge of
nature of science and science related attitudes.

So, to be brief, in India, aims, curriculum, textbooks, techniques, laboratory
facilities, audio visual aids were all subject to criticism. Gangoli and Vasista (1991),
in their report on trend on research in science education in India suggested that
science education research, thus, should direct its attention, (i) in improving the
existing procedures of science instruction, (ii) in establishing new and verified
procedures for teaching science and (iii) to emphasize that science education should
result in the development of abilities and dispositions of mind rather than merely the
transfer of dead subject matter.

It is a right comment by Bose et al. (as cited in Ganguli & Vashista, 1991),
who in their study-report on position of science education in India, assessed that the
state of research in science education in our country had not been encouraging. It had
almost remained restricted to the areas of instructional materials, methodology of
teaching, resources and facilities available in schools for teaching science.

Amidst all these situations, the important aspect of educational developments
in India during the fast few decades, since independence had been the continuous and
sustained effort to evolve a national system of education and to keep revising it to the
contemporary educational and social demands, for which the National curriculum
framework (NCF) were evolved. These literature provide an opportunity to see the
trends in curricular revision of science. Some relevant implications were drawn below
from such literatures which help to build up theoretical formulation for the present
study.

“The curriculum for the ten year school” (NCERT, 1975), in which the
importance of science education was projected as per the recommendation of National
Policy on Education (NPE) 1986, resulted in mismatch between curricular objectives
and actual transaction of curriculum in the classroom. This in turn lead to a wide
spread disparities in the levels of attainment of pupils and in the standard of science
education among schools in different parts of the country. The study, “curriculum
load at school level – A quick appraisal’ (NCERT, 1984) which was conducted to
reorient the content and processes of whole education including science, suggested
minimum levels of learning; strengthening the teaching process by adopting
pedagogical concerns such as child centered approach; facilitating ‘learning how to
learn’, creative expressions, inclusion of scientific temper, utilization of media and
educational technology, continuous and comprehensive evaluation, etc. Following
this, the NCERT (1988) recommended (for upper primary and secondary stages) that
the objectives of science education should be to develop an understanding of nature of
scientific knowledge, and certain physical, chemical and biological principles in
nature as well as in daily life. It suggested that the learner should be helped in
developing the capability of using the processes of science in solving problems, skills
of manipulating simple science equipments, designing of simple experiments, to seek
explanations of natural phenomena, understanding and appreciation of the joint
enterprise of Science, Technology and Society (STS), to deal with quantitative
measurement, collection, presentation and analysis of data and drawing inferences – problem solving and decision making, through the learning of key concepts which cut across all the disciplines of science. The scope of evaluation is to ensure minimum learning outcomes (MLO) in respect of knowledge, concepts, skills interests, abilities, appreciation and values related to the common core components that have been developed at the mastery level in the learners. The transformation in educational and learning system in India and other countries as assessed by literatures like ‘The changes of education’ (India, 1985), ‘A Nation at Risk’ (USA, 1983), and ‘Learning to succeed’ (UK, 1993), ‘Learning the treasure within’ (UNESCO, 1996), give meaningful long range suggestions with a critical look at the total educational scenario. So, the National Curriculum Framework for School Education (NCERT, 1988a) recommended renewed curriculum concerns. The school subject ‘science’, was renamed as ‘Science and Technology’ at secondary level, as it observed that technology deals with numerous ways and means of pressing science into the service of mankind, thus enhancing the quality of human life. So, the turning point was to recognize the strong organic linkage between the two. Science Education should aim at developing well defined abilities in cognitive, affective and psychomotor domains, scientific attitude and interest in learning science processes rather than facts, performing experiments, collection-classification of data, making hypotheses, drawing inferences, etc. The basic philosophy of science was a shift from scientific literary to scientific and technology literary. So, the recommended purpose of sciences education was to fulfill the seven dimensions of scientific literacy like the ability to understand nature of science, process of science, values that under-ly science, joint enterprise of science technology-society; the ability to develop rich and more satisfied view of the universe, appropriate science concepts, ability to develop certain manipulative skills which are required in day to day life situations. It was also recommended to adopt instructional strategies with variety of modes involving activities such as observation, collection of materials informations, demonstration and experimentation, project assignment, field work, educational excursion, role playing creative writing, supplementary reading, etc.
Later, NCF (NCERT, 2005) pointed out a need for qualitative change in science education in India where rote learning should be replaced by inquiry skills – Emphasis on co-curricular, extra-curricular elements, science and technology fair, etc. should be supported – Child should be engaged in learning principles of science through familiar experiences, working with hands to design simple technological units and modules and continuing to learn more on environment and health through activities and surveys – Scientific concepts are to be arrived at mainly from activities and experiments – Systematic experimentation is to be practiced as a tool to discover/verify theoretical principles. Three main problems are identified which was addressed previously by the aims of innovative programmes on science teaching in schools: (i) the sheer weight of concepts and facts taught, (ii) the mismatch between cognitive development of the child and the concept taught, and (iii) the imbalance in teaching methods used in classroom. It is so recommended to have real activity based teaching and more exploratory/investigative activities outside the textbook.

Implications

So, in brief, in India the studies were more scattered on variety aspects of teaching science such as aims, curriculum, textbooks, techniques, lab facilities, audio-visual aids, etc. with less focus on science teacher and his teaching abilities. Majority of studies just pointed out the defects with no constructive proposal to bring out any effects seeking improvement whereas the National Policies on (Science) Education have been proposing to take major shifts from passive reception in learning to active participation in learning, from teacher centric to learner centric, from learning within four wall of the classroom to learning in the wider social context, from traditional methods to investigatory and inquiry based methods, from mere formal activities to non-formal ways; from rote learning of content to mastery learning of competencies; from just ‘science’ to ‘Science Technology and Society’ (STS) base.

2.2 STUDIES RELATED TO TEACHER COMPETENCE AND THE SCIENCE TEACHING COMPETENCE

The process of teaching of any subject including science is a broad phenomenon. Leinhardt and Greeno (1986) Spiro, Coulson, Feltovich and Anderson
(1988): Spiro, Feltovich, Jacobson and Coulson (1991) observed that teaching is a complex cognitive skill occurring in an ill-structured dynamic environment. So doing research in teaching involves many complexities: Dunkin and Medley (Dunkin, 1987) identified ten major categories of variables of research in teaching: In online category there are six (learning outcome, pupil learning activities, interactive teacher behaviour, pre-active teacher behaviour, teacher competencies, pre-existing teacher characteristics) variables and in off-line category there are four (individual pupil characteristics, internal context variables, external context variables, teacher training variables) variables. A research in teaching actually refers to any studies in which one or both variables lies between pre-existing teacher characteristics and pupil learning outcomes. So, in a good research work an effort is to be made to maximize the number of teacher variables (the six online variables and four offline variables) through a comprehensive model and design. Dunkin and Bidle Model (1974), for the study of classroom teaching, identified another set of categorizing teaching variables; (1) presage variables: which include teacher formative background such as sex, class, age, etc., teachers training experiences which includes pre-service teaching, practice teaching and inservice teaching; and teacher properties such as teaching skills, intelligence, motivations, personality traits, etc. (2) process variables: which include the observable classroom behaviour of teacher and the change in pupil behaviour. (3) product variables which include immediate pupil growth effects (growth of knowledge, skill and attitude related to subjects learned) and at long term pupil effect (development of professional skills, adult personality etc.). (4) context variables: which include pupil formative situational experiences in the context of classroom and school community.

Teaching, as a social phenomena has been interpreted with changing conceptualization, that is, by widening the scope and varying the meaning to suit the ever changing socio-cultural base of education. By synthesizing the description as given by Thorndike (1913), Morrison (1934), Ryburn (1961), Gagne (1965), Skinner (1968), Buch (1972), Kauer (1985), Robertson (1987) (as all cited in Menezes, L., 2002) one can summarize the meaning of teaching like this – Teaching, implies a set
of observable teacher behaviours that facilitate or bring about the pupil learning so there is no teaching unless there is learning. Teaching is arranging or facilitating situation or conditions which lead to desirable end, the learning. It is a process carried out in three stages proactive, interactive and post-active. But on the contrary, Husek (1968), Smith (1971), Hough and Durcan (1971), Gage (1972), Jackson (1980) (as all cited in Menezes, L.), Rao (1987), interpreted that teaching is that what teacher does, rather than any reference to what happens to the learner as a result of instructions. So instruction need not result in learning; and to call a classroom activity as an instructional activity, it is enough if the teacher engages in an activity with an intent of modifying student behaviour and need not necessarily be followed by a change in students behaviour. A third type of interpretation is due to Hughes (1963), Amidson and Hunter (1967) Jackson (1968) Bidwell (1973). Mc Neil and Popha (1978) (all as cited in Menezes, L, 2002) who pronounced more on the interaction aspect of teaching. Whether learning does occur or not as a consequence of teaching, the teaching should be an interactive process. Of late, the information processing model of teaching given by Joyce and Weil (1972) and constructivists model of teaching show a clear shift in comprehensive meaning of teaching from teacher centric to child centric, from content base to process-base, from individualized to cooperative (social) mode and from information transfer (lecture) to information processing (activity) mode.

So, after reviewing studies which find different interpretations to teaching, a brief review of studies related to the effort of enhancing teacher capabilities toward a quality science education is made.

According to an Encyclopedia on Science Education “Science education researchers should be willing to develop or adopt ethnographic research strategies that will enable them to describe what is happening in the science classroom before they attempt to modify that environment. A second contributor to classroom ecology is the teacher, who has a prime role to play in the process of effective science education”. The National Research Council USA (NRC, 1996) explains that in science education research, the word change is often associated with a need to improve practice, content
knowledge and attitudes. The USA national science education standards, which proposes that the instructional practices to be taken up by teachers have to improve quality of science education and students academic achievement. It perceives that inquiry-based, student-centered classrooms are highly instrumental in cultivating the desired science teaching and learning culture. Further the teachers role is emphasized in many other research studies. For instance, Wanchoo and Raina (1973) made a remark (which holds good for learning of any subject like science) that the last two decades are characterized by (i) advanced level subject matter at earliest ages and grade levels (ii) contributions of university scholars as principal agents in reformulating the content and processes of instruction at both the primary and secondary levels, (iii) efforts to apply the mode of inquiry in teaching, and (iv) reorganization of content on conceptual schemes that presumably comprise the structure of knowledge within each discipline, all of which are to be perceived by an effective teacher of today. Fullan (1996) comments that one cannot improve student learning for all or most students without improving teacher learning for all or most teacher; teacher and student learning are in-extricably linked.

Darling Hammond and Mclaughlin (as cited in Hiebert et al., 2002) found that teachers learn by doing, reading and reflecting (just as students do); by collaborating with other teachers; by looking closely at students and their work; and by sharing what they see. To understand deeply, teachers must learn about, see, and experience successful learning centred and learner centred teaching. Hamachek (1980) has described three teacher variables on which motivation of students is totally dependent: (a) teacher personality, (b) teacher interaction styles which means use of more praising, sympathizing, encouraging, etc. in place of other type of interaction styles and (c) non-directive versus directive teaching, which indicate the kind and the intensity of either the teacher’s or the students involvement in total classroom process. These studies show the importance of teachers role in bringing out effective learning. A review on studies related to monitoring the teachers teaching process reveals the following.
Tisher and Power (as cited in Oates, 1980), from insights derived from several Australian studies, suggested some specific features of teaching process: (i) Curriculum materials do shape classroom behaviour. Pupils perceive changes in their learning environment when new, enquiry-centred materials replace a traditional, teacher dominated, lecture discussion model of conducting classrooms. (ii) Teacher structuring plays an important role in inquiry-centred classroom. So, pupil make more cognitive gains only when there is additional structuring. And pupils perceive that post structuring leads to greater learning. (iii) There are certain minimal conditions that must be fulfilled in classrooms such as teacher’s knowledge of any curriculum materials, levels of questioning and explaining on the part of pupils, where self paced or enquiry-centred curriculum units are used. So, these points indicate that research in teaching need the use of varieties of observational techniques, student interviews, questionnaires and other data sources if the multi-faceted process of teaching is to be understood more fully.

The process of carrying out a study to analyze their own teaching itself is more important than any significant findings that might emerge.

The studies on knowledge base criteria related to teaching as a professional competence show that when teaching is taken as a professional competence, the teacher’s knowledge base for teaching (Shulman, 1987) or the teacher’s professional knowledge (Tom and Valli 1990), becomes the first and foremost concern. Shulman (1986), Veal and Makinster (1999) emphasized on subject content/matter specific-knowledge base for teaching (SCK or SMK). But as pointed out by Ball and Mac Diarmid (1990), teacher education finds a shift in focus primarily to pedagogy giving an emphasis on general pedagogical knowledge (GPK) of classroom practices which is independent of subject matter. Shulman (1987) introduced the idea of pedagogical content knowledge (PCK) which exists at the intersection of content and pedagogy and represent the blending of these two and provide an understanding of how particular aspects of subject matter are organized, adopted and represented for instruction. So, it is implied that SMK, GPK and PCK forms subcomponent of knowledge base of any subject teacher. Berty (1975) held that the knowledge of
science (SCK) known to the teacher, and the use of textbook and reference materials are positively related to teachers' views of classroom activities that could be used during science instruction and student-teacher relationships. Wilson et al. (1987) found that the above two sets of knowledge SCK and PCK interact and inform each other. At the start of a teacher career, the PCK is fairly thin, but studies have shown that student-teachers recognize the rapid acquisition of the knowledge and mismatch between their SCK and PCK. It is argued that as teacher's progress through their careers, the PCK increases in size and importance, in relation to SCK and that the two inform each other. A term ‘content representation’ (CR) is used to indicate a subset of PCK science teaching. It includes knowledge of (i) instructional strategies that promote learning, (ii) knowledge of student and (iii) their requirements for meaningful science teaching. It includes (Magnusson, Krajcik and Borko, 1999) the knowledge of topic, specific instructional strategies and activities (demonstration, experiments, investigation); strength and weakness of various representation and activities with respect to supporting learning; ability to create and sequence them in such a way to scaffold students developing understanding of science concepts.

But, Cochran, King and Ruiter (1993); Van Driel, Verloop, and Devos (1998) criticized the notion of PCK, the main reason being the confusion in defining its structure which came in the form of the many lists to describe it. For instance, Shulman, Wilson and Richert (1987) in their initial description included additional items such as curriculum knowledge, knowledge of learners, knowledge of educational contexts, knowledge of educational ends – purposes-values. Hence, Van Driel, Verloop, and Devos (1998) questioned the existence of PCK by noting that such a notion of PCK is very trivial and few science topic-specific examples in literature itself provide this idea. However, PCK had become a widely useful and well accepted academic construct (Loughran, 2003). PCK in a common view is that which is bound up –and recognizable –in a teachers approach to teaching particular content pedagogy and understanding of science content. It includes six aspects namely comprehension, transformation, instruction, evaluation, reflection and new comprehension. Mishra and Koehler (2006) extended Shulmans formulation of PCK
to the phenomenon wherein teachers integrate technology into their pedagogy, such as the use of high-tech instructional designs in teaching, to develop a complex situational form of knowledge TPCK (technical PCK). This has three components of learning environment: the content, pedagogy and technology. Floden (1996) used the PCK approach to study about teacher’s knowledge. An era had began in research to focus on understanding teaching from the teacher’s perspective rather than the old approach that focused labeling of teachers teaching behaviours.

Some other modes of descriptions were also tried to describe the teacher’s knowledge base. Biggs (1999, pp. 40-41) identified four kinds of knowledge: (i) declarative – the propositional knowledge, is just knowing about things, (ii) procedural-the skill based knowledge, which is knowing how to respond to a given situation and getting the sequence right, (iii) conditional-knowledge which combines procedural and declarative knowledge at theoretical level; which is knowing when, why and under what conditions a particular course of action is justified, (iv) Functioning knowledge is the knowledge within the learner’s experience that can be put to work.

A few studies were conducted to find interaction between teachers’ knowledge and other aspects of teaching. Studies undertaken by Barnes (1989), Carter (1990), Reynolds (1992) established the interaction between teachers knowledge base with other aspects of teaching, learning, the learners and the subject matter involved. Geddis (1993) considered pedagogical content knowledge PCK as central to the development of preservice teachers thinking about ways of providing learning experiences in the classroom. Zembal-Saul, Krajcik, and Blumenfeld (2001) took up study on enhancement of teaching of science using the concept of content representation (CR). Teaching is treated as a complex cognitive activity that required the transformation of teacher knowledge from diverse domains, including subject matter knowledge (SMK), general pedagogical knowledge (GPK), and knowledge of context (PCK). The findings of the study was that by the end of ‘cycle of instruction’ prospective teachers become more sensitive to issues of science content representation. Gess Newsome (1995) studied biology teachers perceptions of subject
matter structure (SMS) and its relationship to classroom practice. Teachers content competency in the form of SMS was studied using case study and qualitative analysis. Okee Lee (1995) studied relation between subject-matter-knowledge, classroom management and instructional practices in middle school science classrooms. The findings indicated that teacher’s limited knowledge of science content and his strict classroom order resulted in heavy dependence on text book and student individual activities (eg. seat work) and avoidance of whole class activities (eg. discussion).

Rao, T.P. (1987) found that in science classrooms content processes like categorization, application of principles and logical reasoning were meagerly employed that too by a few effective science teachers.

So far, the review have been focused on description of knowledge base that influence science teacher’s approach to, and practices of teaching. However Schon (1983) pointed out the exceptional difficulty of establishing links between practice and knowledge. This is so because the knowledge that tend to influence their practices are often tacit. So it requires special care to design a selective approach for assuming the linkage between teacher’s knowledge and their practices in classroom.

Attitude of teachers towards the subjects and teaching of that subject forms an integral part of teacher competence.

There are many studies conducted on the teachers’ attitude and its effect over students (Scharmann and Orth Hampton, 1995; Reddy R.B., 1978; Devi, 1988; Naik, 1990). It is found that the teachers’ attitude towards teaching has an influence over job involvement, job satisfaction, motivation and so on (Ramakrishnaiah D., 1980; Singh R.S., 1987; Reddy B.P., 1989). Besides this there were certain correlational studies which attempted to study the age, marital status with attitude. So, it can be concluded that teachers attitude do influence teacher competence and professional behaviours.

A brief review of research literature which relate the concept of teacher competence with the meaning of teacher effectiveness was found necessary in order to evolve the broad based meaning of teaching competencies. In the context of explaining the role of teacher in teaching, Medley (1963), Biddle et al. (1964) found
that teacher competence refers to the set of knowledge, abilities a teacher possesses and brings to the teaching situation and hence means the ability of teacher to accomplish the goals to be achieved through appropriate teacher behaviour that produces intended effects.

Meldey (1982) and Anderson (1991) gave a description with a split notion for teacher effectiveness: they used the term teacher competence to indicate the possession of knowledge and skill by the teacher to differentiate it from teacher performance. Teacher performance refers to the use of the knowledge and skills and stands for the teacher behaviour inside and outside the classroom. It does not include pupil component. In this situation teacher effectiveness forms a linking concept between teacher competence and teacher performance.

Teacher effectiveness is always a prime research area and it is getting more importance as the accountability of education in democratic set up is picking up a social-political impetus. Indian national policies on school education (1986, 1992) stress upon teacher’s accountability to pupils, the parents, the community and their own profession. The voluminous compilation produced by many Domas and Tiedman (1950), Castelter and others (1951), Morsh and Wilder (1954), Waiters (1954), Ryans (1960), Barret (1961), Biddle and Ellena (1964), Flanders (1970), Balzer, Evans and Blosser (1973), Travers (1973), Boriel (1977), Buch (1974, 1979, 1986) (all as cited in Nadeem, 1986) all of which speaks on different aspect of teacher effectiveness.

Nadeem (1986) in his analysis on sixty three studies on ‘teacher effectiveness’ extending over three decades remark that the multidimensional concept of teacher effectiveness pose inability to determine the criteria by which a teachers work should be judged. So in all, these studies focus only some combination of presage, process and product variables. The terminologies referred to were such as teaching competency, scholastic competency, teaching efficiency, teaching sciences, etc. The presage variables that have been studied in the investigation conducted in India include – teacher personality attributes, social background of the teacher, achievement in academic course, in-service teacher status, teacher characteristics such as teacher attitudes, interest, intelligence etc. The process criteria described and measured had
been confined to teacher behavior alone, which excludes student behavior. The product criteria had mostly been analyzed in terms of change in pupils overt nonverbal behavior like achievement, pupil liking, etc., without taking cognizance of affective outcomes such as attitudes. The criteria for measurement of teacher effectiveness were mostly rating scale, marks in theory and practice teaching, and classroom observation. Also, independent estimates such as rating by supervisor, students and fellow teachers were very common which were employed for grouping teachers as successful or effective teacher. Age, sex, marital status, size of family were some of the biographical-variables; teaching experience, professional training, academic qualification, locality of work, school system were some of the professional variables; SES, urban – rural, caste – religion were some of the demographic variables included in these studies Nair (1974), Chayya (1975) Passi and Sharma (1982), Srivastava (1980) (as cited in Nadeem, 1986) found that except professional training and academic qualifications all other teacher background variables were found not influencing teachers competency or ability of teaching. But there is inconclusive evidences regarding the relationship of teachers’ teaching experience, age and SES with their effectiveness (Passi and Sharma, 1982; Raina, 1965; Rajgopalan, 1975; as cited in Nadeem, 1986).

Debnath (1971) in his study on teaching efficiency used the method of analytical judgement based on critical observation of a lesson throughout the period. The important correlates of teaching efficiency were listed. The correlating variables were knowledge of subject matter, sincerity in teaching, mastery of the method of teaching, academic qualifications, mode of exposition, sympathetic attitude towards students, discipline, students participations, proper use of aids and appliances in teaching, and the art of questioning. The findings of the study was that the age, experience, academic achievements and professional training were the significant determinates of teaching efficiency. Prasad (1974) used single variable of abilities of teachers in his evaluation of professional efficiency of primary school teachers. The professional efficiency was studied from three angles: (i) efficiency in classroom
teaching, (ii) efficiency in organizing curricular activities and (iii) efficiency in organizing activities related to school community relationship aspects of school life.

Some western studies on teacher effectiveness also project the absence of general framework for determining the teaching work. But the criteria chosen in these studies were found to be comparatively more relevant and broad based as can be seen in the following studies. Bell, Terrel H, and others (1962), Reed H.B (1962), Stern (1967) developed criteria for determining effective teaching with two categories of definition based on the two frame of reference first the teacher and second the quantity and quality of learning. Cassel and Jones (1960) compiled more than one thousand reports of teacher effectiveness, and derived more than twenty two thousand five hundred critical characteristics of an effective teacher which they arranged into three categories: (i) application, (ii) qualifications and (iii) preparation. Teacher application as a dimension of teacher effectiveness was described in six related categories: (i) use of effective teaching techniques, (ii) use of sound and effective psychology, (iii) display of effective human relations, (iv) sound and effective community relations, (v) exercise of effective leadership and (vi) display of sound professional bearings. Secondly, teacher qualifications contained three characteristics: (i) good personality attributes, (ii) sound character pattern, (iii) sound intellectual capability. The third dimension, the teacher preparation was described with two aspects: (i) sound professional preparation and (ii) sound psychological preparation. Spinthall, Whitley and Mosher (1966) selected a proximate criterion for teacher competence or effectiveness, in terms of a set of behaviours in the classroom as an important dependent variable. From these behaviours they attempted to derive a set of concepts pertinent to effective/ineffective teaching, namely, cognitive flexibility versus rigidity. Teaching, in an operational sense, was approached from three perspective: (i) teacher’s personal cognitive characteristics, (ii) teacher’s cognitive attitude towards the pupil and (iii) teachers cognitive attitude towards communication of subject matter. Only a very few studies were available which attempted to determine teaching in terms of teaching competencies of a science teacher. Butzow and Qureshi (1978) conducted a study on competencies of secondary school science
teachers. The purpose of the study was to identify observable competencies for prospective high school science teachers and validate the identified competencies. With a systematic process of interview and analysis of responses, twelve generic competencies in the form of following statements were obtained. A teacher must - know his subject and keep striving to update his/her knowledge - have a good rapport with his/her students - recognize the individual academic abilities of his/her students and try to encourage each of these students - make his/her lessons interesting without wasting time - be able to control the discipline problems in order to protect the learning experiences of his/her students - plan class lessons in advance with the idea to present scientific concepts and ideas in an organized and clear manner - foster unbiased, independent and critical thinking in his/her students - especially the one who is teaching low or average ability students - relate the scientific ideas he/she is teaching to the daily life experiences and the needs of the students – evaluate the academic progress of his/her students with a practical sense and make the results available to them as soon as possible respond to the sudden diversions of students thoughts appropriately take appropriate actions and instruct students about laboratory safety practices - fulfill his/her professional responsibilities. Mathew R. (1980) in his factorial analysis of teaching competencies identified fourteen factors about teacher competency-general teaching competency; competency of teachers concern for students, teaching audio-video-aids, professional perception, giving assignment, illustrating with examples, pacing while introducing; logical exposition; classroom management; use of questions; initiating pupils participations; use of black board; recognizing attending behavior; competency of achieving closure. Most of these factors are just the usual categories of microteaching skills.

Some studies related to assessment of teaching were reviewed. It is found that direct observation of class to measure teacher performance was employed in many studies. Nuthall (1971) in a project took up research by focusing on classroom. Gage (1963) in his study used teaching skill approach where specific task rather than all parts of teaching was employed. Mitz (1971) developed teacher training material ‘Tool of the trade’ on explaining skill and validated it through an experimental study.
Simon and Boyer (1967) developed a set of instruments for the observation of teaching in classroom by name “mirrors of behaviour”. Rao, T.P. (1987) used Nonverbal component teaching skills observation schedule (NVCT, SOS) to study effective science teachers instructional behaviour which consisted of nineteen component skills which were categorised into four types: (i) Nine teaching skills: gestures-movements-focusing behaviours; change in speech pattern, use of different media; use of silence for pupils participation and attending behaviour; use of silence as positive reinforcement; using silence as negative reinforcement; using black board; accepting pupils ideas/feeling; rejecting peoples ideas/feeling. (ii) Four nonverbal activities of science teaching: demonstration; drawing, derivation, involving pupils in the activities. (iii) Three functional nonverbal skills: silence no activity; observation, supervision. (iv) Three non functional nonverbal skills: starting at the corners; erasing the board; certain habitual utterances. The verbal component teaching skills observation schedule (VCTSOS) specifies six skills: introducing a lesson; fluency in questioning; explaining; illustrating with examples; reinforcement; achieving closure. Also a content processing catalogue used in the study lists twenty components categorized in three groups: (i) Nine components of content – fact, idea, law, principle, generalization, preposition, concept, convention, assumption. (ii) Two non-content processing categories: Data recall and fact stating, logical and empirical procedures. (iii) Nine data or content processing processes: analysis of assumptions, inductive thinking, deductive thinking, interpretation of data, categorizing, applying principles, logical reasoning, hypothesizing, hypothesis testing. So, it may be noted that the analysis of classroom instructional process even by direct observation is a complex exercise. Roy (as cited in Travers, 1971) revealed that in determining teacher effectiveness, a pooled judgement is likely to yield better results than just individual assessment.

The indirect approach of determining teacher competencies through students’ performance is seen in some research studies.

This indirect way of assessment is called consequence competencies. It refers to pupil outcomes produced by the teachers’ proper use of an array of knowledge and
performance competencies which can be measured by achievement tests and observation of pupils behaviour in classroom. The American Educational Research Association (1952), Austin and Lee (1966) and many other studies described that the ultimate criterion of a teacher’s competence is his/her impact upon the learner. And one interesting explanation reads like this: discovery of effective teacher though observation of pupil is like the practice of physical scientist who determine presence of an agent by measuring objects quite apart from that agent eg: Existence of Neptune was predicated by perturbation of Saturn’s orbit. Scruggs (1959) has defined teacher effectiveness as the degree to which the teacher produces effects, or the extent to which the teacher causes the attainment of educational objectives. The effects supposed to be produced on the pupils by the teacher were measured in terms of growth of pupils in achieving educational objectives, attitudes of pupils towards the teacher, and the behaviour of pupils in the classroom. But there were also a few counter arguments:

Flanders (1965) found technical problem in the above type of assessment. The problem is concerned about the adequacy of measures for assessing a wide range of student achievement and attitudes at different educational levels in diverse subject matter areas. B.B Brown (1966) also raised philosophical consideration in the question of selecting desirable changes to be brought in learners. Musella (1970) Smith (1967) pointed about the failure to account for instructional variables that the teacher does not control. Lawler’s (1964) view was about the non-reliability of the results of teacher behaviour, that is, inconsistency of progress of pupils under the same teacher. So various views exist about the criteria of focusing on pupils to assess teacher competence or teacher effectiveness. However, it is an established fact that the degree to which teacher produce effect on pupil can be measured by growth of pupils in achieving objectives.

Apart from these direct and indirect type of assessment procedures, some reciprocal type of approaches to measure teacher competence or teacher effectiveness were also tried. One such reciprocal type of approach to understand teaching effectiveness comes in the form of educational productivity or instructional
effectiveness which has a learner centered philosophy. This is the comprehensive model used by Carroll (1963) and Walberg (1984) to describe Instructional effectiveness. Here five classes of variables were identified, which are related to the time required, to achieve a particular learning task. The variables were aptitude, opportunity to learn, perseverance, quality of instruction and ability to understand instruction of the student were identified. Carroll model in fact formed the basis for evolving Bloom’s concept of ‘mastery learning’ (Bloom, 1968) and is also related to ‘direct instruction’ as described by Rosenshine (1983). Later, Creemers proposed a more elaborate model in which three main aspects of quality of instruction namely curriculum, grouping procedures and teacher behavior were distinguished. Yet, another recent development in modeling effectiveness is the emerging new paradigm inspired by constructivism. As a consequence of constructivist thinking, learning strategies, learning to learn, and reflecting on these learning strategies (meta-cognition) had become important in mastering content. Many terms came into existence to describe learning such as ‘active learning’ (Cohen, 1978), ‘situated cognition’ (Resnick, 1987) and ‘cognitive apprenticeship’ (Collins et al., 1988). Duffy and Jonassen (1992) (as cited in Bhaskar & Marlow, 1996) describe the ‘instruction technology’ (based on constructivism) that enable students to construct their own meaningful and conceptually functional representation of the external world. Hence, structuring goals, students learning, learning situations, evaluation of students etc takes new meaning in constructivist foundations.

Implication

From the review of all the above research studies the following implications were drawn. These implications were directly applied while evolving the conceptual structure for science teaching competencies in the present study.

The scenario of teaching the science in India and abroad is changing from a passive reception to active participation of students, teacher centered to learner centered practices, rote learning of content to mastery learning of competencies, classroom-textbook to open school-learning advancements, information transfer to
investigatory projects, etc. All these situations force a science teacher to update his/her knowledge and pedagogical practices in the respective subject area.

Any full pledged fruitful research work on science teaching become more relevant if it proceeds from pre-existing teacher characteristics (teacher competence and interactive teacher behaviour) to pupils’ learning characteristics (learning outcome). It becomes more holistic if it involves as many variables as possible taken from presage, process, product and context types and seeking linkage between these types.

The teachers are projected as centre factor of educational effectiveness. Because teacher’s role is pivotal, his knowledge belief, attitude and related competence, classroom practices directly accounts for quality of Science Education. The competence expressed in terms of teachers professional knowledge can be considered as a sum whole of teachers’ knowledge of Subject matter, General Pedagogy and Pedagogical content (SMK, GPK, PCK). The attitude of teachers towards the subject he or she teaches is also a related component of his/her professional competence.

The knowledge base expressed in the above way is proved to be an established academic construct as supported by several studies abroad. Assessing teaching on the basis of understanding teaching, from teacher’s perspective as conceived by the above knowledge-base structure, begins a new era in studies related to science education in India. Because, in studies conducted so far on science teaching competencies, only competencies of general nature were considered rather than any subject specific ones.

Establishing clear-cut links between teachers knowledge and practices is difficult. Accurate design is necessary for studies related to this question. And so far no clear-cut picture is established in this regard especially in the area of science teaching. Also, studies related to science teacher in respect of their teaching abilities and attitudes are rarely found; even though teachers attitude are correlated to some other general variables such as job satisfaction and classroom efficiencies.

Teacher effectiveness is a more inclusive term when compared to teacher competence. Good number of studies on teacher effectiveness provide useful
information in respect of variables, assessment criteria, etc. for analysing teaching. These informations can be applied to synthesize teaching competence into a broader construct encompassing the functional meaning of teacher effectiveness. To achieve this, appropriate assessment criteria is to be evolved.

Science teaching competencies can structurally be formulated in such a way that the assessment domains extends over three aspects (i) the cognitive knowledge possessed by the teacher – what the teacher knows, believes or ‘cando’, (ii) the performance in the classroom situation – what the teacher does to bring his ‘possession’ to the teaching situation, (iii) the consequence progress brought by the teacher among his students – what the teacher can get their pupils do in attaining the specified goal of science teaching/education.

So, in order to assess the science teaching competencies effectively, pooled data collected by using tools like paper-pencil testing, interview, class observation, etc., related to several component variables are found necessary. Evolving such an assessment profile with multifaceted approach consisting of categories and components spreading over knowledge, skill-performance, affective dimensions requires variety of tools like, observation schedules, skill tests, attitude scales, interview schedules, etc.

Projecting teacher as a central factor of education system requires to be reaffirmed on the basis of advent of constructivism. So, teachers role, mere as a facilitator for providing rich learning environment – is a principle to be amalgamated while conceptualizing the teacher competence.

2.3 STUDIES RELATED TO THE EFFECT OF SCIENCE TEACHING ON PUPILS ACHIEVEMENT

As Skinner puts it in simple words, that a person who is taught learns more quickly than who is not; it looks something very trivial to declare that teaching, in general, brings out learning. But relationship between teaching and learning is neither so simple nor the complexity is, by and large, analyzed so far to the extent of establishing results free from any critique (Nuthall, 2004). Hirst and Peter (1970) and Smith (1967) concluded that the relationship between teaching and learning has been
the concern of philosophers for long, but has rarely been defined in clear terms by those engaged in research on teaching. The studies attempted to establish this relationship (usually under the caption teaching effectiveness) by taking for granted that empirical relationships such as established correlations, between teacher action and student achievement are all that need to be known to establish how teaching relates to learning (Cook, 2001; Winne, 1984). Moreover as pointed out by Gess-Newsome and Lederman (1999), Nuthall (2001), Oser and Baeriswyl (2001), the professional culture of teaching leads to the belief that, if something is taught, it is automatically learned. If a negative result is obtained, it is usually attributed to lack of student’s ability etc, but not to the ineffectiveness of the instruction (Fischer, 1994; Flodden, 1996). The studies which consider teaching as a series of events where in teacher attempts to change the behavior of students along the intended direction provide referential base for inferring teaching-learning relation. The following brief review of research literature gives the trend in Indian studies which reflect effort to relate teaching of science to students’ learning of science.

At the beginning, from 1952 to 1972, there were only thirty eight studies in the area of teaching and these studies included input-process-output ideas. The inputs were presage variables related to teacher or pupil characteristics which are supposed to play a role in the teaching-learning process. The output variables were the product variables which deal with the extent of achievement of pupils on various dimensions like achievement in knowledge, gain in skills, change in attitude etc which occur as a result of the instructional process in classroom. In addition to studies conducted exclusively on presage, process, product there were ‘presage-process’, ‘process-product’ studies, but comparatively less in number. There was only one study conducted with presage-process-product linkage. All these studies projected the complexity of phenomenon of teaching as involving many number of variables with lacks any theoretical or conceptual framework to generalize the results. The number of process-product type of studies which directly help to understand teacher effective behaviours, were fewer when compared to presage-process studies. Classroom observation by FIACS analysis were employed in experimental studies involving
process variables. Most of the experimental studies compared some sort of practically biased approval of instruction with the traditional ‘talk-chalk’ method and branded the former as progressive or effective, without an in-depth analysis (Desai and Roy, 1972; as cited in Buch, 1974). The need to know the concomitant change in the cognitive, affective or psychomotor achievement of students when a particular teacher behavior increased or decreased was pointed out by Jangira and Sharma (1972).

There were two hundred and eleven studies on science education during the last four decades (1952-1992). But only sixty four studies were related directly to science teaching. From 1972 to 1992, there had been a remarkable expansion of structure of studies to cover more presage, process and products variables. The presage variables (teacher factor) cover variables on orgasmic personality, subject competence, professional education and also learner characteristics. In process variables (teacher behavior) teaching skill, teaching competence, teaching style and teaching strategy, teaching techniques, teaching modes, teaching approaches etc were included. The product variables (learning outcome) included physical, cognitive (knowledge) psychomotor (skill), and affective (socio–emotional, attitudes, appreciation, etc.). When the trend was analyzed it was found that nearly half of the number of studies among 109 were related to ‘teacher factor –teacher behavior’ effect only. This indicate a clear preference of research for the type of studies focusing on teacher only. Nearly one fifth of studies belongs to teacher behavior to learning outcome effect. These studies showed a genuine concern to establish process-product link. Only a few studies were taken up on ‘teacher factor – teacher behavior – learning outcome’, but did not prove the sequential link between all the three at a time. These studies just link between the three variables taken only two at a time. The relationships between characteristics of teachers, teaching acts and their effect on educational outcome in the context of classroom teaching measures the teacher effectiveness (Flanders and Simon, 1969). So in technical terms, the studies referred to above could not qualify as studies on establishing teacher effectiveness. Moreover, most of the studies adopted rigorous designs. There was no clear demarcation between theory, concept and operational definition; the distinction between logic and
empiricism was insufficient to support the interpretation and conclusion. Also in all these studies learning outcome criteria other than the scholastic was not tried (Padma, 1979; Dave, 1987; Gangoli and Vashista, 1991). The design used in these studies related to classroom setting were all quasi experimental type. The ‘t’ test, ANOVA and ANCOVA were used for statistical analysis. Innovative methods and model of teaching (mostly CAM, ITM, ADM, JIM) were introduced in addition to the study of effectiveness of lecture, discussion, demonstration, laboratory and methods.

The process–product studies, mostly concerned with achievement as criterion variable were usually based on the principle which tries to identify link between teacher’s in-class behaviours with students learning outcomes. But this relationship is difficult to prove with sufficient consistency and reliability. However through many studies the overall achievement gain provides a possible evidence for the relationship between teaching and learning.

Apart from pupil achievement, the non-cognitive learning outcome forms one of the important product variable. For instance the attitude as a measure of effective outcome expands the dimension of assessment of learning outcome (which is usually restricted only to achievement). Attitudinal aims have been given greater importance particularly in science courses. Howell and Thomson comments that the most potent determinant of our students behaviour in life is not what they know but what they feel and believe. Keeves (1975) used path models and their analysis to study the relationship and interaction between attitude and achievement in mathematics and science and a number of variables in the educational environment. Connion and Simpson (1985) found that attitude toward science appeared to be an important factor in science achievement. Haladyna, Olsen and Shaughnessy (1982 and 1983) suggested that the influence of school and non-school variables on attitude toward science has not been properly considered. While studying the attitudes towards science, it was also reported that small differences exist in attitude between boys and girls; the effect of instructional program on attitude are generally positive; but the variables such as teacher and classroom environment play an important role in affecting attitude. Many studies have attempted to study the students’ attitude towards
Implications

Relation between teaching and learning is neither so simple nor the complexity is by and large analysed fully so far. Many research studies conducted in India during past few decades were exclusively on either presage or process or product. There were also presage-process, process-product studies, but very less in number. The main theme for process-product studies was to measure the outcomes of an instructional process. But more studies are needed to link between variables spread over all the three – the presage-process-product link with variety of inputs. And more studies are needed to know the concomitant changes in the cognitive, affective and psychomotor achievement of students linked to a particular teacher characteristics.

Pupils attitude towards science was found to be related to their science achievement (Cannon and Simpson, 1985). So pupils attitude towards science can be considered as an important product variable.

2.4 STUDIES RELATED TO DEVELOPMENT OF SCIENCE PROCESS SKILLS THROUGH TEACHING OF SCIENCE

It is essential that the emphasis of science education should be on the development of abilities and dispositions of mind rather than merely the transfer of dead subject matter (Ganguli and Vashista 1991). Science as a process of acquiring knowledge gives rise to potential source of science process skills. Scientific method of thinking, the scientific temper or attitude also form as a long term consequence effects of the process structure of science. Few studies on science process skills are reviewed below. Oboarn (1961) (as cited in Lobo, 1987) thus puts these ideas in a nutshell while explaining process skills “all individuals can profit by using these processes of science in finding needed information and in seeking solutions to life’s multitude problems. In this sense every man could be his own scientist – his own problem solver”. Hollins and Whitby (1990), in their research titled progression in primary science, list key process skills like observing, raising questions, measuring, hypothesizing, planning, interpreting along with a more detailed breakdown of what
each of these imply. It was suggested that carrying out investigations is a very important way of developing skills and understanding of scientific process. Serlin (1976) (as cited in Lobo, 1987) emphasized science teaching processes such as hypothesising, experimenting and inferring by implementing discovery laboratory design in introductory college physics course. The criteria followed were like this: The activities were matched to the developmental stage of learners and then guidance was provided by the use of advance organizers, and by describing the nature of science as a discovery activity. The methods used through discovery laboratory were found effective in improving students science process skills. Percy Bridgman (1965) (as cited in Lobo, 1987) identifies six science processes while defining science teaching at school level: (a) accurate and precise description – which means learning of specialized vocabulary, word, item or concept of science, (b) classification – which means learning to group together the items in a given way and to group the things more than one way of classifying, (c) repetition – which means learning to know that reoccurring of events leads to accuracy and control, (d) consensus – which means the process involving reporting a repeated event as probable, (e) experimentation – which means imposing variations in the conditions controlling an event which leads to new and valuable information, (f) measurement – which means particular kind of description through the use of number and mathematical relationships. According to Hurd and Gallagher (1969), the processes of science involve making observations and measurements, drawing inferences, interpreting data, using intuition, generalizing from a few cases to many, making predictions, testing predictions for validity, formulating questions, making assumptions, guesses and experimenting. Many curricular developments and programmes such as Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), Science – A Process Approach (SAPA), and the Physical Science Study Committee Course (PSSC), all in United States of America; and Oxford Primary Science Project (OPSP), Nuffield Science Teaching Project (NSTP) in the United Kingdom, emphasize processes of science as a major outcome in science teaching. Some influence of this approach is found on Indian Education system also. Singh (1971) (as cited in Bhat, P.C., 1982) while
discussing the objectives of science teaching in Indian school says “What is required is that the pupil should observe, measure, classify, use numbers, see relationship, make hypothesis, devise experiments, interpret evidence draw conclusions and verify the findings. Such an approach provides training in the processes of science and leads to a better understanding of science concepts”. Sharan (1977), (as cited in Bhat, P.C., 1982) commenting on the school curriculum in science for Indian Schools, writes “In the preparation of textual material in science greater emphasis is to be laid on the learning principles and fundamental concepts through the practice of processes and problem solving”. So all these literatures and studies imply that science processes characterize the activities of scientists, the way to locate and gather information, explore, search and discover the truths of nature. These processes of science need necessarily to be a part of science teaching.

Some difference in opinion is observed regarding role of science content for developing process skills. Gagne (1965) described scientific enquiry as a terminal objective of science education and declared that the processes are generalizable across content domains and contributes to rational thinking in everyday affairs. Tobin and Capie (1981) (as cited in Lobo, 1987) have pointed out that process skills represent a characteristic way of thinking that should be transferred to other problem situations. If process skills are not tied to the content in which they are learnt, they can be taught in a specific content area and subsequently be used to solve problems from other areas within science, or from subjects such as social science or mathematics. Again, such a view is criticized by the modern philosophers of science (Hadson 1988). Finely (1983) (as cited in Erickson et al., 1998) points out that the science processes are likely to be content bound. It is unlikely that there will be content free intellectual skills that are generalisable across multiple enquiries.

The criticism is not only just restricted to the linkage of content with process skills but also with the basic practice of measuring science process skills as a separate entity Erickson and Meyer (1998) with a thorough and in-depth analysis have made two conclusions: “first, it is not possible to separate unique skills from the task assessment and therefore, not possible to claim to be measuring any of the
conventional unitary traits, such as science process skills, and, second, it is not possible to determine whether responses are based on school-acquired knowledge or out-of-school experiences”.

**Implications**

Developing science process skills in the context of teaching science still retain its significance even though the separate unitary status of these subject specific skills is under scrutiny in the context of its measurement. So, the task assessment could be designed in such a way as to include content oriented process skills as a part of instructional activity. Competencies of an effective science teacher must reflect good understanding about various strategies of developing prime science process skills among students. And efforts for developing science process skills also helps pupil to form a mental base for acquiring the scientific method of thinking and for developing scientific attitude.

Review conducted so far had an objective to assign a broad structure for science teaching competencies by outlining the important domains from which effective science teaching competencies originates. In parallel, a theoretical correlation is drawn between teaching/instructional effectiveness and teaching competence with regard to their logical anomalies to achieve an equivalence between the two constructs. This will in turn help to formulate a set of science teaching competencies with implicit structure of a variable and which could thus independently function as a measure of instructional effectiveness or in more simpler terms, the whole act of a teacher’s teaching science. Such profile of science teaching competencies indicates what a science teacher should possess and what he should deliver to achieve the externally/externally assigned goals which leads to accountability and quality of science education. So improving quality of science education becomes a function of science teaching competencies of science teacher. To improve their competence, in-service science teachers need training. So, with this backdrop the major research activity of the present study is focused on providing in-service training to science teachers with an intention to enhance their science teaching
competencies. In this connection a brief review of studies related to inservice training was also taken up.

2.5 STUDIES RELATED TO TRAINING PROGRAMMES IN SCIENCE TEACHING AND THEIR IMPACT OVER TEACHER COMPETENCE IN SCIENCE TEACHING

Training is an important Human Resource Development activity. Keep (1989) says that training is just one of the instruments at the disposal of the Human Resource Department and other organisation in creating human resource strategy. The inter-relationship between training and recruitment strategies is usually a very close one. If the organisation wishes to improve the skills of its work force, it has the choice of either training its existing employers or recruiting pre-skilled professionals who have been trained elsewhere. So in case of school education, teachers with good pre-service training and in-service teachers who undergo proper re-training to improve their skills and competence, can only prove to be effective.

Holden gave a training cycle based on HRD plan, which consisted of a flowchart of organizational strategy, HRM strategy, analysis of needs, training programme and monitoring and evaluation of these. Hall (1984) pointed out that analyzing training needs is the first step of vital importance in Human Resource Development (HRD), wherein the needful skills and active management of employee learning for their long-range future were identified in relation to explicit organizational strategies. For training to be effective, it is therefore necessary to discern between the training that just cater the individual and group needs, and that which serve their needs to fit into the overall organizational objectives. Bernhard and Ingolis studied on training and its strategic implementation in companies at United States and found that money is being wasted because the fundamental issue of analyzing training needs in relation to the short and long term plans had not been considered. Fairbairns (1991) had rightly opined that an integral part of analyzing training need is to confirm how the proposed scheme fit the company culture. Training scheme that fit one company, may not fit another. Any how this is part and parcel of the organic approach to HRD. So HRD theories specifically put stress on
analyzing needs before designing any training to the employees of any organizational set up like teachers in schools. Rose and Wignanek (1990) recommend dual training system, which is composed of a combination of ‘on-the-job’ and ‘off-the-job’ training. On-the-job training may range from observe and copy method to structured practice. Off-the-job training take the employee away from work environment to a place where the frustrations and bustle of work are eliminated. This enables the trainee to study theoretical information or be exposed to new and innovative ideas. In the field of education teachers under go usually off-the-job type training. A few studies in this field conducted in India are discussed here. Jayamma (1962) (as cited in Buch, 1974) in her research on construction and standardization of an inventory for predicting teacher efficiency showed that the teachers training, experience and qualifications could add to their Professional success. Ramdas (1981) (as cited in Ganguli & Vashista, 1991) conducted experiments designed to demonstrate that without altering text books and other materials in the schools, science teaching can be improved by giving some training to teachers. Systematic observation, interview and written tests were used to assess the effectiveness in terms of changes in teachers and pupil behaviour. Experimental group teachers showed significantly more changes such as willingness to change their teaching method and go beyond the textual material to include real life experiences, to apply concepts in physics to non-textual situations. Singh, S.K. (1987) arrived at the conclusion that remedial instructional microteaching was effective in improving the skills of probing questioning and demonstration of both the group –less experienced teachers and experienced teachers. Kour, A. (1985) found that in-service education and training of teachers had significantly contributed to the development of professional competency in Punjab. The process and structure variables had a positive bearing on the product variables. Teaching competency has a positive correlation with both the process and structure variables. Inservice education was found useful in improving the skills of teachers and had a positive effect on their attitude towards teaching.

Vyas J.C. (1992) evaluated the effectiveness of the programme of mass orientation of school teachers and found that performance of teachers covered under
the programme was better than those who were not oriented. In experimental studies such as finding effectiveness of in-service training two factors pose problems in implementation, viz. (i) Controlling of intersession history of subject and (ii) stabilizing of behaviours of teachers and students. One way of controlling the intersession history of subjects, is that the experiment may be planned for short duration (Rosenshine, 1971). Behaviours of both under-trainees as well as trainer should be stabilized as the novelty effect may contaminate the results. This is reduced by having experiments for a longer duration. So both types of experiments should be conducted. (a) 1-2 weeks in the field (b) 1-3 weeks in the laboratory. Mishra, S. (1992), on the basis of his study concluded that inservice training had a positive impact on teachers’ behaviour and pupils’ active participation in the class. Bloom (1968) and Gallagher (1964) tried to develop desired understanding of nature of science in science teachers on the assumption that teachers conceptions directly translate into their teaching practices and gets percolated in students. Appleton, K. and Asoko, H. (1996) examined the impact of an in-service programme about constructivist approach on teachers progress. The teacher who had undergone this in-service programme and used these ideas in the classroom were found to have improved in their attitude towards teaching, discipline of the subject and students. Darling-Hammond and Sykes (1999) pointed out that professional development yields the best results when it is long term, school-based, collaborative and is focused on students learning, and is linked to curricula. Garet et al. (2001) found that in such professional development programmes, teachers examine student work, develop performance assessments and standard based report cards and jointly plan, teach and revise lessons. And the teachers who traditionally have worked in isolation, report favourably on programmes that bring them in close contact with colleagues in active work on improving practice.

Development and role of subject matter knowledge within teachers professional development is presently the source of much research. Although the parallel development and role of pedagogical knowledge has yet to be systematically analysed. Shulmans model of pedagogical content knowledge as an interaction and
possible moulding of these two domains of knowledge remains as a possible imagination. Because of the studies by Dershimer, M. (1989), Hoz Tomer and Tamir (1990) which showed exceptions about the parallel development role of the two domains. Zembal (1996), Zembal-Saul, Blumenfeld and Krajcik (2000) in their studies adopted what is called as cycles of instruction. This cycle refer to planning, teaching, and reflection associated with teaching a series of lessons around a narrow set of subject specific concepts. Aisiku (1976) explored the feasibility of introducing the skills for structure of knowledge analysis into the training programme for secondary school teachers in Nigeria. The teachers were professionally prepared for an approach for teaching, which mainly emphasizes the dynamic interaction of teachers, students and subject-matter. Teachers who adopted analysis of structure of knowledge approach were successful in gaining higher performance scores in the post-workshop teaching episodes. Besong, M. et al. (2005) studied the role of in-service training in the advancement of STM education where in a descriptive baseline survey method was adopted for a sample of thirty-six secondary school teachers. Semi-structured interview, focused group discussion and knowledge-attitude-practice (KAP) analysis of in-service teachers were the mainly employed strategies. Joyce and Showers (1980 and 1988) undertook a meta-analysis of nearly two hundred studies of the effect of staff development in-service training programmes. The conclusions are summarized in the following table which gives the mean cumulative effect sizes in standard deviation units of different staff development procedures on possible in-service education outcomes.

<table>
<thead>
<tr>
<th>Outcome feature of course</th>
<th>Development of teachers’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knowledge</td>
</tr>
<tr>
<td>Give information</td>
<td>0.63</td>
</tr>
<tr>
<td>+ demonstrate</td>
<td>1.65</td>
</tr>
<tr>
<td>+ opportunity to practice</td>
<td>-</td>
</tr>
<tr>
<td>+ feedback</td>
<td>1.31</td>
</tr>
<tr>
<td>+ coaching in school</td>
<td>2.7</td>
</tr>
</tbody>
</table>

(Source: Innodata Monographs, Philips S. Adey, 1999, UNESCO, IBE, p. 29)
The result implies that the occasional day spent in a university or professional development centre will have no effect, however well structured and organized it may be. Tutoring work in schools is found essential. Theory can be put into practice in teacher’s own classes and the only way to do this is to work with the teachers in their classes by supporting them in the implementation of the training strategies.

Philip S. Adey (1999) implemented an innovative teaching approach called cognitive acceleration through science education CASE originally targeting pupils between the ages of 11 and 14 years and was designed as an intervention programme in the existing curriculum. A professional development programme on CASE (the CASE-PD) was also implemented for teachers as a two year course intended to run in parallel with a school’s initial implementation of the two year Thinking Science Programme. This typical two year CASE-PD programme was arranged at two places, at the centre and at the schools with alternate timings.

The type of materials and literatures used in in-service training programme is of immense importance while providing in-service training to teachers. In the present study an instructional package on science teaching competencies was developed tried for its effectiveness. A few studies were reviewed as a background for designing this instruction package. Regarding the transactional mode in the training programme and their effects especially for the content care of the training programme. Besides, the field observations which provided an impetus in designing the training programme, certain studies related to understanding the nature of science and its effect over classroom teaching; the need for teaching skills such as questioning, explaining effective use of AV aids; knowledge of skills of using various assessment procedures were reviewed. The implications drawn from these studies provided a content framework for the training programme which was the main objective of the study.

Sahajahan in his experimental study to teach science to sixth and seventh standard by using modules, found that modular way of learning is more effective than conventional method. Anjaria (1984) prepared an instructional model for standard ten on the basis of system approach which was found to be more effective in planning the design of the experiment and also in retention of subject matter. Lombhate (1987)
developed an instructional material for rural school teachers of Madhya Pradesh in science in which the use of instructional material by teachers of experimental group contributed towards improvement in their performance. Adinarayan (1984) studied the effectiveness of instructional materials for teachers and proved its effectiveness in developing observational, investigatory and inquiry skills in students. Harrison (1982) and Reid Barrington and Kenney (1992) suggested wide variety of interactive learning techniques for off-the-job training: workshops, case studies, role play, simulations, video-audio tapes problem solving etc. Reid, Barrington and Kenney (1992) suggest that too much lecturing can have a negative effect. Instead a practical experience which would help in their jobs was recommended.

It is very essential to evaluate and monitor the training programme. But there are a few problems. Holden (1991) opines that it is relatively easy to evaluate a formal off-the-job course but much on-the-job training often takes place in an informal way, which is usually subjective and open out to wide interpretations. Some of the tools like questionnaire, test or examinations, projects, case studies, interviews observation, discussion, etc. were suggested as methods of evaluating teachers.

Implications

There are limited number of studies on in-service training of science teachers. In-service training programme is to be strengthened by extending the scope of teacher education as a follow up of studies on student-teachers. The transfer of training competence acquired in pre-service stage can be analyzed later when the student teachers acquire teaching positions in schools. But, this happens to be a longitudinal study. If not possible, at least the status of competence of teachers working in schools has to be analysed before arranging any in-service training usually provided by state education department. In-service training programme, if designed and implemented well, will have a potential to improve overall teaching capabilities of in-service teachers. In-service training programme should have a need based objective, cascaded design with variety of transactional models such as informing, rehearsing, providing feedback, practicing at own school; in sessions with lectures, group discussion, brainstorming, simulation field work, library reference, etc. The NCF 2005 specified that
in-service education is not an event but rather is a process, which includes knowledge, development and changes in attitudes, skills disposition and practice – through interactions both in workshop settings and in the school. It does not consists only of receiving knowledge from experts but also promotion of experiential learning. Review of practice is seen as a part of the overall strategy.

2.6 DISCUSSION

The implicational remarks drawn at the end of each of the five sections of review done so far, are consolidated and synthesized to draw following insights.

1. The quality of science education when considered for any particular region, is dependent more on the quality of prevailing science teaching practices, than all other factors related to education system. The classroom practices of science teachers are decided more by the science teaching competencies they possess, than all other factors related to classroom teaching. So, any purposeful effort to improve the status of science education should begin with the efforts to improve science teaching practices and hence to improve science teaching competencies of the teachers. From the gist of the whole review, it is found that the long track of educational research seems to have not applied any serious thought along this line of thinking. From research point of view there is a necessity to systematize the structure of science teaching as a single entity comprising of well defined set of teacher competencies over many aspects (domains) related to science content and pedagogical concerns. These concerns must be directed towards purposeful interaction between teacher and learner. So, the role of teacher-learner should be the main focus to make the teaching-learning as a successful process in deriving effectiveness and achievement leading to some predetermined and accountable goal. With this background in mind, the criteria of science teaching competence of an effective teacher is formed by a set of teaching competencies defined over broadly outlined domains or sub domains, each of which forms the component aspects of the integrated whole structure of science teaching process. Further, when teaching competence is considered at primary level, it just means the set of knowledge, abilities and beliefs possessed by a teacher about the teaching process.
which he brings to teaching situation. But when the issue in question is achieving accountable goals of science education, the conceptual meaning of teaching competence must be extended to cover teaching effectiveness also. Hence the assessment criteria for teaching competence, as a factor that concerns quality of science education, thus needs three dimensions: (i) what the teacher 'possess' - knows, believes or can do, which can be measured by knowledge based competence and attitude towards science teaching. (ii) What the teacher 'does' to bring his 'possession' to the teaching situation, which can be measured by observing the performance of teacher in actual classroom, (iii) what the teacher can get their pupils to do in attaining the specified goals, which can be measured by the learning or achievement levels of students. When science teaching competencies are formulated with such a multi-dimensional structure the assessment process needs pooled data collected through testing, interview, class observation, etc. The review of literatures on status of science teaching and science teaching competence provides not any clear results derived from any research work related to teachers science teaching competencies, except for the appraisal of science teaching facilities, laboratory equipment, teachers using particular method or pattern of behaviour in classroom. So, the main concern of any research work could be to find answers to questions like, what are the competencies to be possessed by an effective science teacher ? To what extent these competencies are possessed by the teachers who teach science in the schools ?

2. Again, a full pledged-fruitful research work on science teaching become more realistic and holistic if (i) it produces useful results for teachers and teacher educators simultaneously, (ii) it helps to shape the overall teaching act into one, not by bits, (iii) it helps to improve upon the status, not just to know the existing status, (iv) it involves interactions (interview, class observation and feedback) rather than just testing, (v) it involves experimentation to find the effectiveness of any instructional material rather than just developing an instructional material only for the sake of developing, (vi) it involves assessment in terms of pooled data
obtained from knowledge, skill and attitudinal aspects of teacher and learners, (vii) it involves conducting training programme with an inbuilt measure to follow up and help the teachers for effective implementation of new information and practices in their classroom, not just restricted to passing on new information through lectures. Any research work would be much appreciated for its relevancy if it adopts the above aspects of investigation. So, any research must try to answer to another important question – How can an in-service training programme be planned and implemented to enhance the overall science teaching competencies of teacher through a comprehensive research strategy?

3. In order to conduct such a comprehensive research work, the researcher has to do some 'cross-overs’ such as to include as many teaching-variables as possible among all the three types viz. -presage-process-product variables. The review implies the absence of such cross-overs. Process aspect of science education, with the background variable on presage characteristics of teachers, can be monitored to achieve teacher effectiveness in terms of product variables. This powerful linkage aspect provides an ample scope to conduct studies related to improving science teaching competencies levels of teachers by providing in-service training on a pre-analyzed need-based area of science teaching. Improvement in learning levels of students to whom these teachers teach science, provides a reliable evidence for teacher effectiveness also. The present status of science education in India strongly demands such a type of developmental cum experimental type of studies and projects which could result as capacity building programs for science teachers. Teachers capacity building is priority area today, which accounts for streamlining the state expenditure towards a quality science education. So, the fourth question in the series is how to design an descriptive (explorative) – correlational – experimental loop multistage developmental approach as related to the achievement of the objective of improving science teaching competence of target group?

4. Moreover, from the review, it is understood that majority of the doctoral studies in the field of science teaching were over simplified or highly pinpointed and
simulated to keep up the presumed 'sophistication' related to research work at Ph.D. degree level. But, to derive useful results which deserve any functional applicability of findings, the studies based on more naturalistic approach would only be of great use. A research study with quasi-experimental design where in (i) the school set up is not disturbed, (ii) the regularly appointed teachers with their students in intact classes were taken up as samples, (iii) the experimental interventions are introduced without disturbing the calendar events (lessons, tests, holidays, time-table), and (iv) the teachers receive in-service training in the same administrative set up as usually in practice in the region, could only help to draw more reliable conclusions. The final questions that – how to outline the design of an experimental intervention to fit into the natural setting of academic calendar and prevailing practices school system?

Considering the above research questions which have emerged from the review exercise of research studies, it is seen that not many studies are carried out with this focus. So, in any attempt to conduct a study to fulfill the above requirements, firstly, the comprehensive nature of conceptualization of science teaching in terms of teacher competence is to be extracted into a research variable. Secondly, on the basis of this, an appropriate theoretical modeling is to be done before correlating the contemporary teaching practices at the schools, by considering the subject specific nature and structure of science. The design must incorporate sufficient component variables associated with science teaching and a systematic explorative-developmental-experimental multistage approach, based on the rationale of descriptive-correlational-experimental loop.

Due to all these broad based approach and constraints the present study poses sufficient challenge in planning and implementing an experiment, as a pioneer effect in research on science education. Study thereby seeks some useful results which have direct application to present system of science education at secondary school level.

In the next chapter, (as an act of finding the answers for four major questions raised in the discussion above) detailed discussion on the design, instructions and methodology aspects of the study is taken up.