CHAPTER-I
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INTRODUCTION

1.1 Introduction

The education of science teachers has become a matter of great concern internationally, as problems of economics dominate the attention of people and governments. Scientific and technological literacy for all citizens is a stated goal of most modern nations; the production of more and better scientists and technologists is seen as a way of competing in the economic arena and a primary means of the human condition. If science and technological literacy in general is to be improved, and more students are to be attracted to careers in science technology, changes need to be made at the school and college programmes and in particular teacher education programme.

Much research concerning science teaching and learning is responsible for major shifts in science teacher education. Cognitive science has become a research focus around the world since the early 1980s (Georghiades, 2004). Basically, this research reveals that most people learn the kind of science that is useful in places other than the classroom and laboratory, where students are merely expected to repeat what they are told, follow directions, and remember information and results on recall type examinations. Another research field focuses on the Constructivist Learning Model (Bybee et al, 1989; von Glaserfeld, 1987; Yager, 1991). The research seems conclusive; most people learn only when they construct meaning for themselves. Such research must provide the basis for future science teacher education programmes. Without the research base provided by cognitive science and constructivist studies, improved models for science teacher education cannot be developed. Thus it is constructivism that initiated learner-centered approach in education. The National Curriculum Framework (NCF) 2005 strongly supports the constructivist and learner-centered approach in school education.

Learning is a social as well as individual process, and individual’s learning does not occur in a vacuum. Such a position is consistent with a social constructivist orientation. Advocates of such an orientation for example, Milne & Taylor (1995), have suggested that (a) learning involves personal mental construction of knowledge by individuals, (b) learner subscribe to their conceptual structures, not because they are absolute, but because they are viable for them as individuals, and (c) knowledge construction is a social and cultural process mediated by language. The development
of metacognitive strategies is seen as a crucial element in developing constructivist-oriented classrooms (Gunstone, 1994; Paris & Winograd, 1990). Further Baird, Freshman, Gunstone & White (1991) have argued that “constructivism complements metacognition in effecting personal change” and “adequate metacognition empowers the learner to undertake the constructivist processes of recognition, evaluation and revision of personal views.” Metacognitive strategies are integral and necessary functionaries in constructivist classrooms where their ability to interpret and transform information in a given social setting and monitor their progress while doing so are essential.

Thomas (1999, 2002) has argued that students’ metacognition is socially mediated and that the nature of the classroom learning environment is an important factor influencing the development of students’ metacognition. Keeping this in mind, researcher had decided to study the development of metacognitive skills through constructivist approach.

1.2 Theoretical Framework

1.2.1 The Importance of Metacognition

Reasons for the growing interest in metacognition over the past three decades relate not only to the anticipated improvement in learning outcomes, through interventions that aim at developing students’ metacognition, but also to the broader rise in interest in cognitive theories of learning. However, as Brown (1987) points out in a review of the origins of metacognition, ‘metacognitive processes’ have been recognized and advocated by educational psychologists (Dewey, 1910; Thorndike, 1914) well before the emergence of the term ‘metacognition’. especially in the area of reading and writing. John Locke, for instance, used the term ‘reflection’ to refer to the ‘perception of the state of our own minds’ or ‘the notice which the mind takes of its own operations’ (Locke, 1924). The importance of the concept of reflected abstraction to human intelligence was later discussed by Piaget (1976), who pointed out the need for making cognitions statable and available to consciousness, at which point they can be worked on and further extended (Campione, 1987). Notably, the work of Piaget was introduced to many in the US by Flavell (1963), maintaining a profound impact on Flavell’s writings and the development of his notion of metacognition. ‘Introspection’, a technique used by early psychologists to find answers to psychological questions, was also a first sign of interest in metacognitive processes.
The definition of ‘introspection’ as ‘the reflection on one’s own conscious experience’ (Butler & McManus, 1998) makes such connection all too obvious.

In searching for the origins of metacognition others go far beyond the twentieth century. As Spearman (1923) points out:

_Such a cognizing of cognition itself was already announced by Plato. Aristotle likewise posited a separate power whereby, over and above actually seeing and hearing, the psyche becomes aware of doing so. Later authors, as Strato, Galen Alexander of Aphrodisias, and in particular Plotinus, amplified the doctrine, designating the processes of cognizing one’s own cognition by several specific names. Much later, especial stress was laid on this power of ‘reflection’, as it was now called by Locke._

Hard as it might be to pinpoint the exact origins of metacognition, it is by far easier to reach agreement over the fact that recent attention in metacognition has resulted in the reawakening of interest in the role of consciousness, awareness or understanding in thinking and problem-solving (Campione, 1987).

Following a review of the many different historical roots from which metacognition has developed; Brown (1987) warned that ‘... metacognition is not only a monster of obscure parentage, but a many-headed monster at that’. The acknowledged complexity of the notion of metacognition is also successfully reflected in Flavell’s (1987) remark that although metacognition is usually defined as knowledge and cognition about cognitive objects (i.e. about anything cognitive), the concept could reasonably be broadened to include anything psychological, rather than just anything cognitive. In his attempt to identify where metacognition fits in ‘psychological space’ Flavell (1987) suggested that concepts that may be related to metacognition include executive processes, formal operations, consciousness, social cognition, self-efficacy, self-regulation, reflective self-awareness, and the concept of psychological self or psychological subject. The diversity of perceived meaning and the multidimensional nature of metacognition are therefore without question, a conclusion that was reached by numerous studies in the past, and is discussed in this chapter.

1.2.2 Metacognition

Metacognition, a term introduced in the 1970s by Flavell (1971, 1979, 1987), is often defined as one’s knowledge, awareness and control of the domain of cognition (Brown, Bransford, Ferrara, & Campione, 1983), or as thinking about one’s
own thinking. It entails conscious reflection on what one knows about a given task, and demonstrating ability to describe what s/he is currently doing, talk about his/her feelings about the learning situation in which s/he is engaged, and use this information to monitor and enhance one’s performance (Georghiades, 2006).

Metacognition was originally referred to as the knowledge about and regulation of one’s cognitive activities in learning processes (Flavell, 1979; Brown, 1978). Under the umbrella of this inclusive definition a proliferation of metacognitive terms has unfolded through the years (Veenman, Van Hout-Wolters & Afflerbach, 2006).

Flavell (1979), the founder of research on metacognition, defines metacognition as “thinking about thinking”. He distinguishes between two components of metacognition: (a) knowledge of cognitive processes and products; and (b) ability to control, monitor, and evaluate cognitive processes. Flavell (1979) argues that knowledge of cognition depends on the following inter-related components: metacognitive knowledge about self, the task and strategies; knowledge about how to use the strategies; and metacognitive experience. The later refers to one’s feeling about being successful (or unsuccessful) in performing the task. According to this model, the metacognitive knowledge leads to strategy use, which in turns affects the metacognitive experience, which affects the acquisition of metacognitive knowledge and so on.

Apart from it Flavell (1976) defines metacognition as "active monitoring and consequent regulation and orchestration of cognitive process to achieve cognitive goals". Flavell and Wellman (1977), and Flavell (1979) included interpretation of ongoing experience, or simply making judgments about what one knows or does not know to accomplish a task, as other features of metacognition. Along with the notions of active and conscious monitoring, regulation, and orchestration of thought process, Flavell believed through repeated use of metacognition, it might in time become automatized (Eslami-Rasekh & Ranjbary, 2003).

Metacognition "focuses on people's self-monitoring and self-control of their own cognitions" (Nelson, Narens, & Dunlosky, 2004) and has been extensively used in educational psychology to help in understanding how people learn (Byars-Winston, Fouad, 2006). Baird (1990) also defined metacognition as the “knowledge, awareness and control of one’s own learning” (Case & Gunstone, 2006).
Metacognition consists of two components: knowledge and control (Flavell, 1976). *Metacognitive knowledge* pertains to one’s knowledge about how one’s cognition operates, whereas *metacognitive control* pertains to how one controls one’s cognitive operations (Otani & Widner, Jr., 2005).

According to Winne & Perry (2000) *Metacognition* refers to the awareness that learners have about their general academic strengths and weaknesses and of the cognitive resources they can apply to meet the demands of particular tasks and, second, to their knowledge and skill about how to regulate engagement in tasks to optimize learning processes and outcomes. Chang-Wells and Wells (1995) describe metacognition as “knowledge about one’s own mental processes and the control of those processes to achieve one’s intended goal.” However, there appears to be no uniform definition of metacognition in the literature (Larkin, 2006). Veenman et al. (2006) highlighted the ongoing concern raised by Wellman (1985) that metacognition is a fuzzy concept that lacks coherence and that means many things to many people often varying as a function of the researchers’ personal subscriptions or identifications with a given research paradigm and/or view of the world. They note that, “...while there is consistent acknowledgement of the importance of metacognition, inconsistency marks the conceptualization of the construct”. This issue is evident within the science education literature where metacognition has been defined as, for example, knowledge, control and awareness of learning processes (Baird 1986; Baird & White, 1996; Thomas & McRobbie, 2001) and the ability to think about one’s thinking (Gilbert, 2005).

This confusion probably has at least two sources. First, metacognition has two separate but related aspects: (a) knowledge and beliefs about cognitive phenomena, and (b) the regulation and control of cognitive actions. Flavell’s (1976) now generally accepted description captures these two facets: "Metacognition" refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data.... Metacognition refers, among other things, to the active monitoring and consequent regulation and, orchestration of these processes in relation to the cognitive objects on which they bear, usually in the service of some concrete goal or objective. A second reason for confusion is that even with such an agreed-on description, it is not always easy to distinguish what is metacognitive from what is cognitive. One way of viewing the relationship between them is that cognition is involved in doing, whereas
metacognition is involved in choosing and planning what to do and monitoring what is being done (Garofalo & Lester, 1985).

Most conceptualizations of metacognition have in common that they take the perspective of “higher-order cognition about cognition.” There is a higher-order agent overlooking and governing the cognitive system, while simultaneously being part of it. This is the classical homunculus problem or Comte’s paradox: One cannot split one’s self in two, of whom one thinks whilst the other observes him thinking. The issue whether cognition and metacognition can be disentangled is not merely an academic one. In fact, metacognition draws on cognition. It is very hard to have adequate metacognitive knowledge of one’s competencies in a domain without substantial (cognitive) domain-specific knowledge, such as knowledge about relevant concepts and theories in a domain, about intrinsic difficulties of a domain, and about what is irrelevant (Pressley, 2006). In terms of metacognitive skills, one cannot engage in planning without carrying out cognitive activities, such as generating problem-solving steps and sequencing those steps. Similarly, one cannot check one’s outcome of a calculation without comparing the outcome with an estimation of it, or recalculating the outcome in another way.

If metacognition is conceived as (knowledge of) a set of self-instructions for regulating task performance, then cognition is the vehicle of those self-instructions. These cognitive activities in turn are subject to metacognition, for instance, to ongoing monitoring and evaluation processes. This circular process of metacognitive and cognitive activities makes it hard to disentangle them in the assessment of metacognition. Occasionally, metacognition can be observed in students’ verbalized self-instructions, such as “this is difficult for me, let’s do it step-by-step” or “wait, I don’t know what this word means.” Metacognition, however, is not always explicitly heard or seen during task performance. Instead, it has often to be inferred from certain cognitive activities. For instance, doing things step-by-step may be indicative of planned behavior, although self-instructions for planning are not explicitly verbalized. Future research has to differentiate far more precisely between explicitly verbalized metacognitive knowledge and self-instructions, cognitive activities that are indicative of metacognition, and purely cognitive activity.

Despite their intertwined relation with cognitive processes, metacognitive skills cannot be equated with intellectual ability (Sternberg, 1990). There is ample evidence that metacognitive skills, although moderately correlated to intelligence,
contribute to learning performance on top of intellectual ability. On the average intellectual ability uniquely accounts for 10 percent of variance in learning, metacognitive skills uniquely account for 17 percent of variance in learning, whereas both predictors share another 20 percent of variance in learning for students of different ages and background, for different types of tasks, and for different domains (Veenman, Wilhelm & Beishuizen, 2004; Veenman & Spaans, 2005). The implication is that an adequate level of metacognition may compensate for students’ cognitive limitations.

In the end Schraw & Moshman (1995) version of metacognition help us to further elaborate this concept which says “metacognition includes two main subcomponents generally referred to as knowledge of cognition and regulation of cognition.” First we understand the metacognitive knowledge component and then metacognitive regulation component to get complete understanding of metacognition.

1.2.3 Metacognitive Knowledge

Metacognitive knowledge is categorized in two ways. One way of categorization was given by Flavell (1979) and other way of categorization was given by Schraw & Moshman (1995).

1.2.3.1 Flavell model of Metacognitive Knowledge

According to Flavell (1979) Metacognitive knowledge (MK) refers to the part of our world knowledge that has to do with cognition, and it can be divided into three categories: knowledge of (a) person, (b) task, and (c) strategy variables. Only the acquired intuition about the interaction of these three categories of knowledge enables one to internalize this knowledge and to use it in regulating one’s own cognitive activity (Flavell, 1987; Wellman, 1985). Furthermore, a learner does not have MK until he or she is able to explain adequately why a particular strategy is helpful in a certain cognitive activity (Brown, 1987; Annevirta & Vauras, 2001, 2006).

According to Flavell (1979), metacognitive knowledge refers to acquired knowledge about cognitive processes; knowledge that can then be used to control cognitive processes. Knowledge is considered to be metacognitive (rather than cognitive) if it is actively used in a strategic manner to ensure a goal is met. Flavell distinguishes between knowledge of (1) person variables, (2) task variables and (3) strategy variables:

Knowledge of person variables—refers to knowledge about how human beings learn and process information, as well as individual knowledge of one’s own
learning processes. Metacognitive knowledge included in the person category consists of what one believes about oneself and others as cognitive beings. Examples of research findings relevant to this category are (a) older children predict their performance on serial recall tasks much better than younger children (Flavell, Friedrichs & Hoyt, 1970); (b) young children predict their performance on motor tasks much better than on recall tasks (Markman, 1979); and (c) older children realize that memory ability varies with individuals and tasks and believe that they study differently and can recall information better than younger children can (Kreutzer, Leonard & Flavell, 1975).

*Knowledge of task variables*—includes knowledge about the nature of particular tasks or more generalized knowledge about types of task as well as the processing demands that will be placed upon the individual. Knowledge falling in the task category includes knowledge about the scope and requirements of tasks as well as knowledge about the factors and conditions that make some tasks more difficult than others. Some pertinent research findings include (a) most second and sixth graders believe that familiarity with story content facilitates story comprehension and that preferred stories are easier to read than disliked ones; (b) younger readers and poorer comprehenders view reading as a decoding activity, whereas better comprehenders view reading as a search for meaning (Canney & Winograd, 1979); and (c) 9- and 10-year-olds are more likely than 7-year-olds to predict that categorized groups of items are easier to recall than noncategorized groups (Moynahan, 1973).

*Knowledge about strategy*—variables include knowledge about both cognitive and metacognitive strategies, as well as conditional (contextual knowledge) about when and where it is appropriate to use such strategies. Metacognitive knowledge about strategies includes having knowledge of general and specific cognitive strategies along with an awareness of their potential usefulness for approaching and carrying out certain tasks. The metacognitive aspect of such knowledge lies in knowing where it can be used and in knowing when and how to apply it. Purely rote strategy usage, although it does involve cognition, does not involve metacognition. Examples of relevant research findings include (a) older children can think of more mnemonics and retrieval strategies and also exhibit more planfulness than younger children, and (b) good readers can adjust their reading strategies to fit the specific
purposes at hand, and the ability to adjust strategies gradually increases with age and reading ability (Armbruster, Echols, & Brown, 1983).

The examples above not only illustrate what is meant by metacognitive knowledge but also demonstrate that such knowledge is not always cleanly categorizable. Many of the foregoing examples can be placed in more than one category. For example, the fact that good readers have different reading strategies for different purposes represents knowledge falling in the interaction of the task and strategy categories. Examples of this same interaction appear in the research literature on memory strategies. Brown, Smiley, and Lawton (1978) report that college students, in selecting retrieval cues for future recall, shifted their choices of cues as they learned more and more of the material. Thus their strategies changed as a function of their state of knowledge of the task. Thus it is very difficult to cleanly categorize the subcomponent of metacognitive knowledge. Like the above categorization another way of categorization was given by Schraw & Moshman (1995).

1.2.3.2 Schraw & Moshman model of Metacognitive Knowledge

According to Schraw & Moshman (1995) knowledge of cognition refers to what we know about our cognition, and may be considered to include three subcomponents.

The first, *declarative knowledge* (knowing what factors influence human cognition), includes knowledge about ourselves as learners and what factors influence our performance. For example, most adult learners know the limitations of their memory system and can plan accordingly.

The second, *procedural knowledge* (knowing how certain skills work and how they should be applied), in contrast, refers to knowledge about strategies and other procedures. For instance, most adults possess a basic repertoire of useful strategies such as note-taking, slowing down for important information, skimming unimportant information, using mnemonics, summarizing main ideas, and periodic self-testing.

Finally, *conditional knowledge* (knowing when certain strategies are needed and why they influence cognition) includes knowledge of why and when to use a particular strategy. Individuals with a high degree of conditional knowledge are better able to assess the demands of a specific learning situation and, in turn, select strategies that are most appropriate for that situation.
According to Flavell (1979), metacognitive knowledge plays an important role in many cognitive activities. It is activated deliberately when the nature of the learning task requires conscious thinking and accuracy, when the task is new, or when learning has not been correct or complete. However, it may appear automatically, evoked by retrieval cues in the task situation, and finally, it may and probably does influence the course of the cognitive enterprise without itself entering into consciousness (Flavell, 1979). The literature reviewed notes that metacognitive knowledge characterizes the approach of expert learners to learning, it enhances learning outcomes, facilitating recall, the comprehension of written texts, the completion of new types of learning tasks, it improves the rate of progress in learning, and the quality and speed of learners cognitive engagement. Of special relevance, however, is the influence of metacognitive knowledge in the self-regulation of learning, i.e. in planning, monitoring and evaluating. According to the literature, it is a prerequisite to self-regulation, helping learners to become active participants in their own performance rather than passive recipients of instruction and providing the knowledge base for effective planning, monitoring and evaluating (Perkins & Salomon, 1989). More specifically, the review has shown how metacognitive knowledge influences planning, evaluating and monitoring in the self-regulation of learning that is regulation of cognition.

1.2.4 Metacognitive Regulation

Regulation of cognition typically includes at least three components, planning, monitoring, and evaluation (Schraw & Moshman, 1995).

Planning involves the selection of appropriate strategies and the allocation of resources. Planning includes goal setting, activating relevant background knowledge, and budgeting time. Previous research suggests that experts are more self-regulated compared to novices largely due to effective planning, particularly global planning that occurs prior to beginning a task. Planning skills make children think in advance of how, when, and why to act in order to obtain their purpose through a sequence of sub goals leading to the main problem goal. Planning involves in a classroom context analyzing exercises (e.g., ‘it is a division exercise in a number-problem format’), retrieving relevant domain-specific knowledge and skills (e.g. how to do divisions) and sequencing problem solving steps (e.g., division of the hundreds, tens, units in mental mathematics).
Monitoring includes the self-testing skills necessary to control learning. Adults monitor at both the local (i.e., an individual test item) and global levels (i.e., all items on a test). Further, even skilled adult learners may be poor monitors under certain conditions (e.g., Pressley & Ghatala, 1990). Monitoring skills can be described as the self-regulated control of used cognitive skills during the actual performance, in order to identify problems and to modify plans. Monitoring is related in a classroom context to questions such as ‘am I following my plan?’, ‘is this plan working?’, ‘Should I use paper and pencil to solve the division?’ and so on. Proficient students are assumed to select appropriate skills and adjust behavior to changing task demands, making use of the awareness of previously knowledge and selecting appropriate study behavior (Montague, 1990).

Evaluation refers to appraising the products and a regulatory process of one’s learning. Typical examples include re-evaluating one’s goals, revising predictions, and consolidating intellectual gains. A last metacognitive skill, the evaluation skill, can be defined as the reflections that take place after an event has transpired (Brown, 1987), whereby children look at what they did and whether or not this led to a desired result. Specifically children reflect on the outcome and the understanding of the problem and the appropriateness of the plan, the execution of the solution method as well as on the adequacy of the answer within the context of the problem (Vermeer, 1997). Evaluation makes children in the classroom evaluate their performance and compare task performance with people and use the final result in locating the error in the solution process (Lucangeli et al., 1998).

Thus metacognitive regulation includes planning, monitoring and evaluating the learning as well as learning process. As researcher has discussed, metacognition includes metacognitive knowledge and metacognitive regulation, it is interesting to see what is the relation between metacognitive knowledge and metacognitive regulation, how they are related, what is the correlation between the two.

### 1.2.5 Relation between metacognitive knowledge and metacognitive regulation

Most believe that the two components of metacognition, knowledge of cognition and regulation of cognition, are related. There remain questions, however, about the exact relationship between the two components. Schraw (Schraw, 1994, 1997; Schraw & Dennison, 1994) and others have considered this question. For instance, some work suggests that it is possible that knowledge of cognition is a
prerequisite to regulation of cognition (Baker, 1989). Schraw and Dennison (1994) provided some evidence to suggest that knowledge of cognition may precede regulation of cognition. Using a self report measure of metacognition, they reported that knowledge of cognition was a better predictor of performance on a reading comprehension test than was regulation of cognition. Further, those with high knowledge of cognition were more likely to demonstrate greater regulation of cognition. Although in the Schraw and Dennison study the relationships between metacognitive components yielded statistical significance (r=.54 and r=.45), each made unique contributions, leading the authors to state the two did not share a compensatory relationship.

In other work, Schraw (1994, 1997) further addressed the relationship between knowledge and regulation of cognition. In the 1994 study, he reported that knowledge and regulation of cognition were significantly related only for those with high monitoring ability. Further, when addressing domain-generality of metacognitive regulation, Schraw (1997) employed a self-report measure of metacognitive knowledge and his findings indicated that those scoring lower on the knowledge measure were also less able to accurately monitor their performance while the opposite was true for high monitors. Combined, these studies lend additional support that metacognitive knowledge and regulation are related.

This established the fact that metacognition includes metacognitive knowledge and metacognitive regulation and using both this component in combination for learning something makes it metacognitive skills.

1.2.6 Metacognitive Skill

In recent research on metacognition, a distinction between metacognitive knowledge and metacognitive skills has been made (Schraw, 2001). On the one hand, metacognitive knowledge refers to the individual’s declarative knowledge of learning strategies, person and task characteristics which are relevant mastering a specific situation (Flavell and Wellman, 1977). On the other hand, metacognitive skills refer to the control, monitoring, and self-regulation activities that take place when learning and solving problems (Brown, 1978; Bannert & Mengelkamp, 2008).

Since Flavell introduced the concept of metacognition in 1976, most authors agree that the construct can be differentiated into a knowledge and skills component. Metacognitive knowledge can be described as the knowledge, awareness, and deeper understanding of one’s own cognitive processes and products (Flavell, 1976).
Metacognitive skills can be seen as the voluntary control people have over their own cognitive processes (Brown, 1987). Metacognition was found to be instrumental in challenging tasks in mathematics, not overtaxing the capacity and skills of children and in relatively new skills that are being acquired (Carr & Jessup, 1995; Desoete, 2008).

Brown (1978), an active researcher in this area, believes that the metacognitive skills involved in the intelligent control of one's activities while engaged in a reading or memory task are not different from those involved in successfully performing other cognitive tasks. In particular, such metacognitive skills are deemed crucial in mathematical performance, particularly problem solving. Not only are these regulatory metacognitive behaviors important in mathematical performance, but so are the person, task, and strategy categories of metacognitive knowledge (Lester & Garofalo, 1989).

Metacognitive skills concern the procedural knowledge that pertains to the actual regulation of, and control over one’s cognitive processes and learning activities (Brown, 1978; Flavell, 1992; Schraw & Moshman, 1995). They are occasionally referred to as executive skills (Kluwe, 1987). Task analysis, planning, monitoring, checking or evaluation, recapitulation, and reflection are behavioural manifestations of such skills that are (metacognitively) initiated during task performance. These skills can be acquired and eventually executed implicitly, though some argue that awareness of their metacognitive nature is prerequisite (Nelson, 1996).

Metacognitive skills appear to be highly interdependent. By means of thorough orientation on the task, a metacognitively skilled student is likely to focus on relevant information given in the task assignment, necessary for building an adequate task representation. Consequently, a detailed action plan can be designed, containing goals and directions for subsequent learning activities. Such an elaborate action plan entails the possibility of process control during task performance. Working systematically according to that plan may enable the student to keep track of progress being made. Evaluation or monitoring activities, which are necessary for detecting faulty procedures and mistakes, are more fruitful within the framework of such an action plan. Finally, elaboration activities like drawing conclusions, recapitulating, and generating explanations are more helpful if they are based on a clear trace of activities (Veenman et al., 1997, 2005).
The metacognitive skill component refers to the control of an individual’s ongoing cognitive processes. Flavell (1979) argued that learners must learn to use their MK and self-directive capabilities to steer their cognition and feelings during learning performance. Brown (1980) referred to the other component of metacognition as executive control processes, which included planning, monitoring, and evaluation of an individual’s cognitive and affective functioning. Thus, these self-regulatory strategies entail the operation of specific mental processes by which individuals organize and monitor their thinking. The prevailing self-regulated models also include performance strategies that improve learning or other cognitive functions by helping learners to correct their study behaviors and to repair deficits in their understanding (e.g., Brown & Campione, 1996; Zimmerman, 2000). With planning strategies, a learner plans one’s use of cognitive strategies, such as activating prior knowledge, organizing the material to be read, and so on, whereas metacognitive activities refer to the monitoring of comprehension when learners check their understanding against some self- or other-set goals. The monitoring process suggests the need for a regulation process.

This suggests that a metacognitive skill includes knowledge of cognition and regulation of cognition. When student use declarative, procedural and conditional knowledge and planning, monitoring and evaluating they are said to be consciously engaged in using metacognitive skills. On the other hand, MS will also become automatic without much conscious awareness resulting from practice and habitual use (e.g., Schneider & Pressley, 1989), and it will become conscious mainly in new or difficult situations. Some researchers (Nelson, 1996) claim that metacognition must be conscious in order to represent higher-order processing. Others (Veenman, Prins & Elshout, 2002) allow less conscious processing to be metacognitive by nature, for instance, if ideas about oneself have been firmly established or if the activity of checking yourself has become a regulatory ‘good’ habit. Many evaluation and self-monitoring processes run in the ‘background’ of the cognitive processes that are being executed. Only after an error is detected, rightfully or not, the system becomes alerted. Recently, most researchers’ definitions lie in between (Schneider and Weinert, 1990; Veenman, 1993): Metacognition is conscious or at least accessible to consciousness when difficulties during task performance such as comprehension problems or errors occur.
Apart from the question of conscious or automatic metacognitive processes it is very important to understand the development of metacognitive skills. That is in which stage of development the metacognitive skills develop.

1.2.7 Developmental Processes in Metacognition

From the literature on metacognition development (Brown, 1978; Flavell & Wellman, 1977; Kuhn, 1999), the following picture emerges. Theory-of-Mind develops somewhere between the age of 3 to 5 years (Flavell, 2004; Lock & Schneider, 2006). In the years thereafter, metamemory and metacognitive knowledge develop, but continue to do so during life span (Alexander, Carr & Schwanenflugel, 1995). Metacognitive skills emerge at the age of 8 to 10 years, and expand during the years thereafter (Veenman & Spaans, 2005; Veenman et al., 2004). Moreover, certain metacognitive skills, such as monitoring and evaluation, appear to mature later on than others (e.g., planning). Research by Whitebread (1999, 2005), however, has shown that the behavior of very young children (say, 5 yr. olds) may reveal elementary forms of orientation, planning and reflection if the task is appropriated to their interests and level of understanding. Most likely, metacognitive knowledge and skills already developed during preschool or early-school years at a very basic level, but become more sophisticated and academically oriented whenever formal educational requires the explicit utilization of a metacognitive repertoire.

Evidently, one needs to know more about what components of metacognition develop when and under what conditions? Moreover, we need to know how the development of a metacognitive component contributes to the subsequent development of other ones. For instance, longitudinal research by Lock and Schneider (2006) reveals that a higher level of Theory-of-Mind leads to improved metamemory in the following years, even when confounding factors are controlled for. Similar research for sequential developmental effects in other components of metacognition is needed.

Alexander et al. (2006) showed that metacognitive knowledge develops along a monotonic incremental line throughout the school years, parallel to the development of intellectual ability of students. The impact of intelligence neither increases, nor diminishes over the years. Similarly, Veenman et al. (2004) obtained similar results for the development of metacognitive skills in relation to intellectual ability. In other words, intelligence only gives students a head start in metacognition, but it does not further affect its developmental course.
It seems that metacognitive skills initially develop in separate domains, and later on become generalized across domains (Veenman & Spaans, 2005). It needs to determine the processes that are responsible for this transfer across domains along the developmental trajectory. These processes include, amongst others, high road transfer, and linking metacognition through instruction and feedback provided by teachers. Additionally, examination of the connection of metacognitive development in formal educational settings and other settings is needed.

To better understand the development of metacognitive skills it is necessary to assess properly the developed metacognitive skills. There are so many methods available to assess the metacognitive skills.

1.2.8 Assessment of Metacognition

The evolution in understanding metacognition is paralleled by an evolution in our understanding of assessments that are suitable for measuring and describing metacognition (Pellegrino, Chudowsky, & Glaser, 2002). Many methods for the assessment of metacognition are being used, such as questionnaires (Thomas, 2003), interviews (Zimmerman & Martinez-Pons, 1990), the analysis of thinking-aloud protocols (Afflerbach, 2000; Veenman, Elshout & Groen, 1993), observations (Veenman & Spaans, 2005), stimulated recall (Van Hout-Wolters, 2000), on-line computer-logfile registration (Veenman et al., 2004), and eye-movement registration (Kinnunen & Vauras, 1995). All these assessment methods have their pros and cons. One clear distinction in assessment methods pertains to off-line versus on-line methods (Van Hout-Wolters, 2000; Veenman, 2005). Off-line methods are presented either before or after task performance, whereas on-line assessments are obtained during task performance. On-line methods appear to be more predictive of learning performance relative to off-line methods, even when the latter are administered retrospectively to task performance (Veenman, 2005, 2006).

The mainstream of those tools are addressed to assess the metacognition prospective or retrospective to specific performances. In prospective methods, such as self-report questionnaires and hypothetical interview, students have to indicate on a Likert-type of scale to what extent a statement (e.g., ‘I ask myself questions to make sure I know the material I have been studying’) is representative of their behaviour (Elshout-Mohr et al. 2003; Vermunt, 1996). Retrospective techniques, both questionnaires and interviews have also been applied to assess metacognition (e.g., Artelt, 2000). An obvious problem with retrospective assessment questionnaires is the
risk of memory distortions due to the time lag between the actual performance of problem solving and the verbal reports afterwards. In addition to prospective and retrospective techniques, concurrent assessment, such as think-aloud protocols can take place. In thinking-aloud protocol analysis participants are instructed to merely verbalize their thoughts during task performance.

Despite all the emphasis on metacognition, several problems emerge in the assessment of metacognition making study outcomes difficult to compare (e.g., Artzt and Armour-Thomas 1992; Pressley 2000). On the one hand, Veenman and his colleagues seems skeptical and point to the lack of accuracy and the limited explained variance of learning outcomes of prospective and retrospective assessment methods, such as self report questionnaires. On the other hand, concurrent-assessment techniques, such as think aloud protocols were found to be accurate but time-consuming techniques to assess metacognitive skills.

1.2.8.1 Thinking Aloud Method

When the thinking aloud method is employed, participants are asked to talk aloud during thinking, problem solving, and/or learning, and these verbal protocols are analyzed by means of coding schemes (Afflerbach 2000; Ericsson and Simon 1993; Pressley and Afflerbach 1995). The aim is to identify cognitive and metacognitive processes underlying task performance in different subject areas and contexts. Although this method is frequently used in psychological and educational research, it has been criticized from the very beginning till today (Afflerbach, 2000). To summarize, this criticism mainly concerns two problems. The first one refers to the question of the reactivity of the method: Is the process of thinking altered throughout the method of think aloud because thinking aloud needs resources of the cognitive system that could otherwise be used for the primary task? The second problem refers to the completeness of the verbal protocols: Are the protocols obtained by think aloud procedures complete or is any information about the cognitive processes missing?

To overcome these problems multi-method techniques seem indicated to get a good picture of metacognitive skills (Veenman, 2005; Veenman et al. 2006). Because multi-method assessment is extensively time-consuming, teacher questionnaire can be used to get a good picture of metacognitive skills in elementary school children. Although some researchers question the trustworthiness of teacher questionnaire data, reviews indicate that teachers’ judgments can serve as worthy assessments of
students’ achievement-related behaviors triangulated with data gathered by other protocols (Winne and Perry, 2000). Furthermore teacher’s perception of students’ use of skills was found to be an important predictor of academic performances in children with learning disabilities (Meltzer et al., 1998; Desoete, 2008).

In order to understand this disparity between various assessment methods, we need research with multi-method designs, which at present is scarcely available in the literature on metacognition (Veenman & et al., 2006).

It could be concluded that metacognition has many definitions and meanings, and hence, researcher chose to present here two models that were used in this study for the purpose of analysis of the data. These two models include almost all the main components of metacognition given by different cognitivist. Thus these two models are highly aligned with the nature of metacognition that has the potential to be developed in constructivist learning environments.

1.2.9 Models of Metacognition

The first model is based on Schraw’s (1998) definition of metacognition and is similar to Yore & Treagust’s (2006) conception of metacognition. According to this model, there are two main components in the metacognition:

1. Knowledge of cognition refers to what individuals know about their own cognition or about cognition in general. It includes at least three different kinds of metacognitive awareness: declarative, procedural, and conditional knowledge.

   - Declarative knowledge includes knowledge about oneself as a learner and about factors that influence one’s performance (knowing ‘about’ things).
   - Procedural knowledge refers to knowledge about doing things. Much of this knowledge is represented as heuristics and strategies (knowing ‘how’ to do things).
   - Conditional knowledge refers to knowing when and why to use declarative and procedural knowledge (knowing the ‘why’ and ‘when’ aspects of cognition).

2. Regulation of cognition refers to a set of activities that help students control their learning. Although a number of regulatory skills have been described in the literature, three essential skills are included in all accounts: planning, monitoring, and evaluation.
• Planning involves the selection of appropriate strategies and the allocation of resources that affect performance.

• Monitoring refers to one’s on-line awareness of comprehension and task performance.

• Evaluating refers to appraising the products and efficiency of one’s learning.

The structure of metacognition according this model is illustrated in Figure 1.

Regarding the constructivist learning activity, knowledge of cognition should be reflected during the discussion about the observations by asking appropriate questions and operating a suitable inquiry stage. Regulation of cognition should be expressed during the planning of the experiment, while performing it, and evaluating the results regarding the assumption. Figure 1.1 illustrates the metacognition’s structure of Schraw (1998).

Figure 1.1
The metacognition’s structure of Schraw (1998)

![Diagram of metacognition structure]

The second model is based on Flavell, Miller & Miller (2002) who suggest dividing the metacognition into two central components: one component is called metacognitive knowledge and the other is metacognitive monitoring and self-regulation. They argue that metacognitive monitoring and self-regulation are “one’s management of one’s cognitive activity during problem solving”. This component of metacognition resembles Kuhn’s metacognitive knowledge (Kuhn, 1999; 2000) and Schraw’s regulation of cognition (Schraw, 1998), and it is expressed during problem solving and inquiry activities. According to Flavell et al. (2002) “metacognitive
knowledge refers to segment of your acquired world knowledge that has to do with cognitive matter. "Metacognitive knowledge can be roughly subdivided into knowledge about persons, tasks, and strategies."

The person category includes any knowledge and beliefs one has concerning what human beings are like as cognitive processors. It includes cognitive differences within people, cognitive differences between people, and cognitive similarities among all people.

The task category has two subcategories. One subcategory is concerned with the nature of the information that is encountered in any cognitive task. The other subcategory concerns the nature of the task demands (for example, to know that it is easier to recall the abstract of a story than its exact words).

The strategy subcategory includes knowledge about which strategy is effective for a certain cognitive goal: in comprehending X, remembering Y, solving problem Z, and so on. The metacognitive learner knows what tasks are worth investing efforts, which knowledge is required to achieve the goal, and what is the best way to get this knowledge. Figure 1.2 illustrates the structure of metacognition regarding this framework.

Figure 1.2
Metacognition’s components of Flavell et al. (2002)
After understanding the concept of metacognition researcher searches the relation between constructivism and metacognition which is discussed below.

1.2.10 Relation between Constructivism and Metacognition

Understanding learning is a complex task. Theories regarding how people learn abound and attempting to make sense of such theories can be a daunting task. Learning is a social as well as an individual process; an individual’s learning does not occur in a vacuum. Such a position is consistent with a social constructivist orientation. Advocates of such an orientation, for example, Milne and Taylor (1995), have suggested that (1) learning involves personal mental construction of knowledge by individuals, (2) learners subscribe to their conceptual structures, not because they are absolute, but because they are viable for them as individuals, and (3) knowledge construction is a social and cultural process mediated by language. The development of metacognitive students is seen as a crucial element in developing constructivist-oriented classrooms (Gunstone, 1994; Paris & Winograd, 1990). Further, Baird, Fensham, Gunstone and White (1991) have argued that “constructivism complements metacognition in effecting personal change” and “adequate metacognition empowers the learner to undertake the constructivist processes of recognition, evaluation and revision of personal views”. Metacognitive students are integral and necessary functionaries in constructivist classrooms where their ability to interpret and transform information in a given social setting, and monitor their progress while doing so, are essential. Thomas (1999, 2002) has argued that students’ metacognition is socially mediated and that the nature of the classroom learning environment is an important factor influencing the development of students’ metacognition.

Learning environments facilitating peer interaction potentially support learners to share different perspectives on a problem, justify their perspectives, and arrive at a common perspective through negotiation. Peer interactions potentially expand learners’ awareness of what they need to learn. Studies in science education also revealed that learning environments, especially the constructivist learning environment, are closely related to students’ metacognition (Schraw et al., 2006). Schommer-Aikins’ (2004) Embedded Systemic Model hypothesized that students’ perceptions of classroom learning environment bearing the characteristics of constructivist learning strategies may be related to students’ metacognition. The findings revealed that when students’ use of their metacognition increased, their perception of their learning environment as a place where they had an opportunity to
share and discuss their learning with other students was also increased. The result further revealed that students’ metacognition contributed to their perception of learning environment in that they perceived their learning environment as a place where they can find opportunity to learn science as tentative, and culturally and socially determined.

Regarding multiple regression analysis results metacognition contributed to model more than epistemological belief for all dimensions of Constructivist Learning Environment Scale (CLES). This suggests that while students were getting better in use of their metacognition, they were also getting better in perceiving the characteristics of the constructivist learning environment. Regarding personal relevance dimension of CLES, as students regulate their cognition, they go through several thinking processes in order to link the out-of-school experiences with in-school experiences or vice versa during their science courses. For instance, they think about the validity of information, obtain data from different sources, and make appropriate inferences (Pintrich, 2002). In other words, they use their metacognition to make appropriate transfer of knowledge obtained from in-school and out-school experiences (Bransford et al., 1999). Thus there are enough evidences available which suggest that there is relation between constructivism and metacognition.

Currently, many educationalists conceive of learners as ‘architects building their own knowledge structures’ (Wang, Haertel and Walberg, 1993). The view of the learner has changed from that of a passive recipient of knowledge to that of an active constructor of knowledge. Current learning perspectives incorporate three important assumptions:

- learning is a process of knowledge construction, not of knowledge recording or absorption;
- learning is knowledge-dependent; people use current knowledge to construct new knowledge;
- the learner is aware of the processes of cognition and can control and regulate them; this self-awareness, or metacognition (Flavell, 1976) significantly influences the course of learning (Anthony, 1996).

These assumptions suggest that knowledge construction and awareness of construction of knowledge that is metacognition goes hand in hand. Both seem to be two side of the same coin. If students are provided with learning environment which
encourages them to discuss the content, control and regulate their learning the metacognition can be develop in them.

Although metacognitive activities are not easily triggered in novice learners, they can be guided and facilitated by peer interaction. Verbal interactions are regarded as the most effective form of peer interaction for knowledge construction (Palincsar, 1986; Palincsar & Brown, 1989; Webb, 1989). Flavell and his colleagues (1995) suggest this metacognitive ability changes with age, and that older children are more successful learners because they have internalized a greater quantity of metacognitive information.

We have since learned that the development of metacognitive abilities occurs in tandem with constructivist learning (Terhart, 2003). Constructivist pedagogy requires attention to the development of students’ meta-awareness of their own thinking and learning (Richardson, 2003). Constructivism is congruent with adult learning theory and has potential for the development of metacognitive skills that are an important facet of active and self-directed learning. Metacognitive skills enable students to develop as independent learners by enabling them to become self-managers and appraisers of their own thinking and learning (Peters, 2000). These findings suggest that there is some relationship between constructivism and metacognition which need to be further explored to substantiate this relationship in terms of concrete evidences. But before that, researcher tried to understand the concept of constructivism to further explore the relationship with metacognition.

1.2.11 Definition of Constructivism

Constructivism is first of all a theory of learning based on the idea that knowledge is constructed by the knower based on mental activity. Learners are considered to be active organisms seeking meaning. Constructivism is founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world consciously we live in. Each of us generates our own "rules" and "mental models," which we use to make sense of our experiences. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences.

The goal of constructivism is to help facilitate the learner’s ability to construct knowledge (Brandt, 1997). Students make sense of their surroundings by assimilating new information into the mental models they have previously created and into what they have previously understood. Instead of having the knowledge “poured” into them, students learn by interacting with their environment, exploring that
environment, and constructing knowledge from the experiences. They form rules through reflection on their interaction with objects and ideas (Sprague & Dede, 1999). When they encounter an object, idea, or relationship that does not make sense to them, they either interpret what they see to conform to their rules, or they adjust their rules to better account for the new information (Brooks & Brooks, 1993).

Constructions of meaning may initially bear little relationship to reality (as in the naive theories of children), but will become increasing more complex, differentiated and realistic as time goes on.

Jonassen (1991) talks about constructivism as follows:

Constructivism, founded on Kantian beliefs claims that, reality is constructed by the knower based upon mental activity. Humans are perceivers and interpreters who construct their own reality through engaging in those mental activities...thinking is grounded in perception of physical and social experiences, which can only be comprehended by the mind. What the mind produces are mental models that explain to the knower what he or she has perceived.... We all conceive of the external reality somewhat differently, based on our unique set of experiences with the world and our beliefs about them.

Teaching philosophy based on the concept that learning (cognition) is the result of 'mental construction' students constructs their own understanding by reflecting on their personal experiences, and by relating the new knowledge with what they already know. Each student creates his or her own 'schemas' or mental-models to make sense of the world, and accommodates the new knowledge (learns) by adjusting them. One of its main principles is that learning is search for meaning, therefore, to be effective; a teacher must help the student in discovering his or her own meaning. Although based on cognitive psychology research, its history goes back to the ancient Greece, the Socratic Method.

Bednar, et al (1991) elaborate further....the learner is building an internal representation of knowledge, a personal interpretation of experience. This representation is constantly open to change, its structure and linkages forming the foundation to which other knowledge structures are appended. Learning is an active process in which meaning is developed on the basis of experience....Conceptual growth comes from the sharing of multiple perspectives and simultaneous changing of our internal representations in response to those perspectives as well as through cumulative experience. Consistent with this view of knowledge, learning must be
situated in a rich context, reflective of real world contexts, for this constructive process to occur and transfer to environments beyond the school.

One of the common threads of constructivism that runs across all these definition is the idea that development of understanding requires the learner to actively engage in meaning making. In contrast to behaviourism, constructivists argue that knowledge is not passively received but built up by the cognizing subject.

### 1.2.12 Characteristics of Constructivism

Most constructivists agree on four characteristics that permeate all learning (Jonassen, 1991). These characteristics are outlined below.

- Learners construct their own understanding
- New learning depends on current understanding
- Learning is facilitated by social interaction
- Meaningful learning occurs within authentic learning tasks

The physics education research group at University of Massachusetts defines the premises of constructivism as epistemology as follows:

1. Knowledge is constructed, not transmitted.
2. Prior knowledge impacts the learning process.
3. Initial understanding is local, not global.
4. Building useful knowledge structures requires effortful and purposeful activity.

The meaning of constructivism varies according to one’s perspective and position. Within educational context there are philosophical meanings of constructivism, as well as personal constructivism as described by Piaget (1967), social constructivism outlined by Vygotsky (1978), radical constructivism of Von Glasersfeld (1995) and constructivist epistemologies and educational constructivism of Mathews (1997). Social constructivism and educational constructivism (including theories of learning and pedagogy) have had the greatest impact on instruction and curriculum design because they seem to be the most conducive to integration into current educational approaches.

### 1.2.13 Faces of Constructivism

Dougiamas (1998) describes the major "faces of constructivism" separately. Each of these types of constructivism is "points of view", perspectives loosely defined by a collection of writings of particular individuals in each case.
Trivial constructivism

The simplest idea in constructivism, root of all the other shades of constructivism described below, is trivial constructivism (von Glasersfeld, 1990), or personal constructivism or cognitive constructivism. In this principle, Knowledge is actively constructed by the learner, not passively received from the environment.

Radical constructivism

Radical constructivism adds a second principle to trivial constructivism (von Glasersfeld, 1990): Coming to know is a process of dynamic adaptation towards viable interpretations of experience. The knower does not necessarily construct knowledge of a "real" world.

Social constructivism or Socio-Constructivism

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

Cultural constructivism

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

Critical constructivism

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

Constructionism

Constructionism asserts that constructivism occurs especially well when the learner is engaged in constructing something for others to see.

Cybernetic Constructivism

This is based on the concept of autopoiesis (self-formation) which was formulated by the Chilean cell-biologists Maturana & Varela (1980, 1987). The constructivist character of autopoiesis is manifested at the level of the closure of the nervous system implying that action and cognition depend on each other without any outside system of reference. According to von Foerster (1993) "my nervous system
does not, indeed, cannot, tell me what is "out there," not because of mechanical but because of logico-semantic reasons. My nervous system cannot tell me anything because it is "me": I am the activity of my nervous system, all my nervous system talks about is its own state of sensory-motor activity."

1.2.14 Contrasts between Cognitive and Social Constructivism

The theories of cognitive and social constructivism are based on a somewhat similar epistemology but differ in the degree to which social interaction is seen as influencing individual cognitive development. Piaget, representing the cognitive constructivist view, highlighted individual construction of knowledge in response to interaction in the physical world, but stressed the primacy of individual cognitive development as a relatively solitary act apart from the social con-text (Russell, 1993). On the other hand, social constructivists, such as Vygotsky (1978) and later Bruffee (1986), emphasized the primacy of social interaction as the driving force and prerequisite to individuals' cognitive development through internalization of ideas encountered in the sociocultural realm. Social interaction for Piaget is characterized as "the imposition of adult functions on biologically determined stages of cognitive development" (Russell, 1993). This suggests that it is important for formal instruction to be paced so that students receive the right assistance at the particular stage when they need it. Students must arrive at a developmental stage at which they can accommodate and assimilate information of a given level of sophistication. By contrast, social constructivists do not view learning as occurring in stages; instead they describe a constant reinterpretation, a constant reweaving of the "web of meaning" (Vygotsky), a constant" reconstruction of experience" (Dewey) as human beings consciously... evolve new social practices ... to meet human needs, to adapt to and transform their environments. (Russell, 1993) Moving in the opposite direction from Piaget, social constructivists maintain that interaction in the collective is a necessary precondition for engaging in self-regulation. Self-regulation as a process is achieved when individuals are able to find their authentic voice during problem solving by using the mediational tool of language. Vygotsky (1978) believed that isolated learning cannot lead to cognitive development. He firmly maintained that social interaction is a prerequisite to learning and cognitive development. That is, knowledge is co constructed and learning always involves more than one person. Vygotsky situated learning in the ZPD (Zone of Proximal Development), which he posited as being the distance between the actual developmental level as determined by
independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. It is clear that Vygotsky believed that interaction with others and with the cultural environment contributes to human cognitive development if the interaction takes place within the zone of one's potential development. Current theory posits that language students and future language teachers can obtain opportunities to develop their cognition by actively communicating with others who are more proficient, and thereby expand each other's conceptual potential. Thus, within the ZPD (i.e., each individual's zone of potential learning) more capable students can provide peers with new information and ways of thinking so that all parties can create new means of understanding. This mutually beneficial social process can also lead more experienced students to discover missing information, gain new insights through interactions, and develop a qualitatively different way of understanding. That is why researcher has decided to use social constructivism as a base for the constructivist approach to be used in the present study.

1.2.15 Constructivist Approach

Essentially, the constructivist approach in the teaching of science stipulates that teachers should apply certain strategies and methods which involve students in constructing the desired meaning of scientific concepts and which help the students undergo the desired conceptual changes (Nussbaum, 1999).

Fosnot (1996) argues that the primary goal of a constructivist approach to teacher education is to facilitate new ways of knowing: If understanding the teaching/learning process from a constructivist view is itself constructed, and if teachers tend to teach as they were taught, rather than as they were taught to teach, then teacher education needs to begin with these traditional beliefs and subsequently challenge them through activity, reflection, and discourse in both coursework and field work through the duration of the program. Most importantly, participants need experiences as learners that confront traditional views of teaching and learning in order to enable them to construct a pedagogy that stands in contrast to older, more traditionally held views.

Traditional teaching methods tend to discount the ambiguous, complex, and continually changing world of today (Kanuka & Anderson, 1999). A constructivist teaching approach is less structured, allowing for learning activities to be designed that help student’s function in this rapidly changing environment. According to
Brooks and Brooks (1993), students taught using a constructivist approach develop a deeper comprehension of the material as opposed to memorizing facts, imaginatively solve problems rather than follow procedure, and probe complex issues rather than recite culturally accepted beliefs.

In constructivist approach, faculty serve as guides, monitors, coaches, tutors, coordinators, advisors, and facilitators. The focus of teaching is one of guiding the learner, focusing on knowledge construction rather than knowledge transmission (Slavin, 1994).

It is the faculty member’s job to provide the enabling tools and environments to allow for meaningful knowledge construction (Ackermann, 1995). Driver, Aasoko, Leach, Mortimer, and Scott (1994) described the role of the teacher in the constructivist classroom as “... to introduce new ideas or cultural tools where necessary and to provide the support and guidance for students to make sense of these for themselves ... to listen and diagnose the ways in which the instructional activities are being interpreted to inform further action”.

1.2.16 Basic Assumption for Incorporating Constructivist Approach

- Knowledge is constructed from experience
- Learning is a personal interpretation of the world
- Learning is an active process in which meaning is developed on the basis of experience
- Conceptual growth comes from the negotiation of meaning, the sharing of multiple perspectives and the changing of our internal representations through Collaborative learning
- Learning should be situated in realistic settings; testing should be integrated with the task and not a separate activity (Merill, 1991, in Smorgansbord, 1997).

1.2.17 About the Constructivist Model Used

Researcher’s first problem was to find an appropriate model of constructivism to utilize in the study. Good (1993) acknowledged that several versions of constructivism exist in the literature and that one person's version of a constructivist style may differ significantly from another person's version. Therefore it was important to locate a "tried and true" model of constructivism for this study. Several successful formats based on the constructivist philosophy were located and reviewed. After much study, a model developed by the Biological Sciences Curriculum Studies (BSCS) based on the Science Curriculum Improvement Study (SCIS) learning cycle,
was selected. As Glasson and Lalik (1993) point out, the SCIS learning cycle provides an ideal framework upon which to build a working model of constructivism because it encourages students to interact with peers concerning challenging instructor-generated questions as they develop their understanding of science.

Rodger Bybee, the chief developer of the constructivist plan, based the format of the new design on five instructional phases: Engage, Explore, Explain, Elaborate and Evaluate. According to Bybee (1993):

- the *Engage* is presented to excite the students in the topic;
- the *Explore* directs the students to examine the topic in small groups;
- the *Explain* allows the students to describe to others what their team has discovered;
- the *Elaborate* encourages the students to further investigate the topic;
- the *Evaluate* provides the students a way to assess what they have learned.

The model was selected because it accurately parallels the processes involved in scientific study. Discoveries are made because someone wants to learn more about a topic, gathers information, and develops new insights, scrutinizes the affirmations with colleagues, and evaluates the findings. Aspects of conclusions that are not congruent with the new knowledge are altered, discarded or investigated further.

In addition, the model is student centered and positions the teacher in the role of a "developer" rather than a "disseminator" of knowledge. With Bybee's "5E" model teachers construct opportunities that allow students to incorporate new experiences and new ways of thinking about things. In the past students in Science were expected to acquire new information that had no meaning to them and, therefore, no previous foundation on which to build new knowledge.

They were taught to view science objectively rather than with imagination and understanding. As a result, professors commonly planned their lessons based on the content they found in the textbook and other resource materials, and the students were asked to replicate the information to demonstrate their learning. While information replication is important to some degree in the life sciences, it does not necessarily confirm comprehension and application.

1.2.18 The BSCS 5E Instructional Model

Since the late 1980s, BSCS has used an instructional model consisting of the following phases: engagement, exploration, explanation, elaboration and evaluation. Although the BSCS model was created prior to the NRC synthesis of cognitive
research, that research provides support for the model. Following is a quotation from *How People Learn* (Bransford, Brown, & Cocking, 1999). An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to take major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. The quotation presents a research based recommendation that uses terms to describe an instructional sequence that very closely parallels the BSCS 5E Instructional Model. The BSCS model provides experiences and time for students to recognize the inadequacy of their current ideas, to explore new ways of explaining the world, to reflect on their thinking, and to construct new conceptions of the natural world.

In 2006, the National Research Council (NRC) of America published *America’s Lab Report: Investigations in High School Science*. This report further supports the use of instructional models such as that used by BSCS. In the analysis of laboratory experiences, the committee also applied results from cognitive research. Researchers have investigated the sequencing of science instruction, including the placement and role of laboratory experiences, as these sequences enhance student learning.

The NRC committee proposed the phrase ‘integrated instructional units’. Integrated instructional units interweave laboratory experiences with other types of science learning activities, including lectures, reading, and discussion. Students are engaged in forming research questions, designing and executing experiments, gathering and analyzing data, and constructing arguments and conclusions as they carry out investigations. Diagnostic, formative assessments are embedded into the instructional sequence and can be used to gauge the students’ developing understanding and to promote their self-reflection on their thinking. The BSCS 5E Instructional Model meets the criteria for integrated instructional units described above. Note also the inclusion embedded assessments and the connection of those experiences to students’ self-reflection, or metacognition. This recommendation aligns explicitly with the evaluation phase of the BSCS model. However, each phase of the instructional model provides an opportunity for embedded assessment. Each phase allows teachers and students to assess different aspects of the students’ growing understanding of science and abilities of scientific inquiry.
1.2.19 How does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?

Because learning does not occur by way of passive absorption, the lessons in this module promote active learning. Students are involved in more than listening and reading. They are developing skills, analyzing and evaluating evidence, experiencing and discussing, and talking to their peers about their own understanding. Students work collaboratively with others to solve problems and plan investigations. Many students find that they learn better when they work with others in a collaborative environment than when they work alone in a competitive environment. When active, collaborative learning is directed toward scientific inquiry, students succeed in making their own discoveries. They ask questions, observe, analyze, explain, draw conclusions, and ask new questions. These inquiry-based experiences include both those that involve students in direct experimentation and those in which students develop explanations through critical and logical thinking. The viewpoint that students are active thinkers who construct their own understanding from interactions with phenomena, the environment, and other individuals is based on the theory of constructivism. A constructivist view of learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

This module provides a built-in structure for creating a constructivist classroom: the 5E Instructional Model. The 5E model sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model leads students through five phases of learning that are easily described using words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate. These all five phases, activities in each phase and student and teacher activities in each phase are represented below.
**Engagement**

This phase of the instructional model initiates the learning task. The activity should make connections between past and present learning experiences, anticipate activities, and focus students’ thinking on the learning outcomes of current activities. The student should become mentally engaged in the concept, process, or skill to be explored.

<table>
<thead>
<tr>
<th>The Student…</th>
<th>Explain activities</th>
<th>The Teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Asks questions such as:</td>
<td>• Initiates the learning task. The activity should make connections between past and present learning experiences, and anticipate activities and organize students’ thinking toward the learning outcomes of current activities.</td>
<td>• Raises questions and problems.</td>
</tr>
<tr>
<td>• Why did this happen?</td>
<td>• Generate interest.</td>
<td>• Elicits responses that uncover students’ current knowledge about the concept/topic.</td>
</tr>
<tr>
<td>• What do I already know about this?</td>
<td>• Access prior knowledge.</td>
<td>• Generates interest.</td>
</tr>
<tr>
<td>• What can I find out about this?</td>
<td>• Connect to past knowledge.</td>
<td>• Generates curiosity.</td>
</tr>
<tr>
<td>• How can this problem be solved?</td>
<td>• Set parameters of the focus.</td>
<td></td>
</tr>
<tr>
<td>• Shows interest in topic.</td>
<td>• Frame the idea.</td>
<td></td>
</tr>
<tr>
<td>• Responds to questions demonstrating their understanding.</td>
<td></td>
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</tr>
</tbody>
</table>

Table 1.1

The Students and Teachers Activities during Engagement phase of 5 ‘E’ model
**Exploration**

This phase of the teaching model provides students with a common base of experiences within which they identify and develop current concepts, processes, and skills. During this phase, students actively explore their environment or manipulate materials.

**Table 1.2**

The Students and Teachers Activities during Exploration phase of 5 ‘E’ model

<table>
<thead>
<tr>
<th>The Student…</th>
<th>Explain activities</th>
<th>The Teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Thinks creatively within the limits of the activity.</td>
<td>• Provides students with a common base of experiences which current concepts, processes, and skills are identified and developed.</td>
<td>• Elicits responses that uncover students’ current knowledge about the concept/topic.</td>
</tr>
<tr>
<td>• Tries alternatives to solve a problem and discusses them with others.</td>
<td>• Experience key concepts.</td>
<td>• Raises questions and problems.</td>
</tr>
<tr>
<td>• Suspends judgment.</td>
<td>• Discover new skills.</td>
<td>• Acts as a facilitator.</td>
</tr>
<tr>
<td>• Conducts activities, predicts, and forms hypotheses or makes generalizations.</td>
<td>• Probe, inquire, and question experiences.</td>
<td>• Observes and listens to students as they interact.</td>
</tr>
<tr>
<td>• Becomes a good listener.</td>
<td>• Examine their thinking.</td>
<td>• Asks good inquiry-oriented questions.</td>
</tr>
<tr>
<td>• Shares ideas and suspends judgements.</td>
<td>• Establish relationships and understanding.</td>
<td>• Generates interest.</td>
</tr>
<tr>
<td>• Record observations and/or generalizations.</td>
<td></td>
<td>• Generates curiosity.</td>
</tr>
<tr>
<td>• Discuss tentative alternatives.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Explanation**

This phase of the instructional model focuses students’ attention on a particular aspect of their engagement and exploration experiences and provides opportunities for them to verbalize their conceptual understanding, or demonstrate their skills or behaviours. This phase also provides opportunities for teachers to introduce a formal label or definition for a concept, process, skill or behaviour.

<table>
<thead>
<tr>
<th>The Student…</th>
<th>Explain activities</th>
<th>The Teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Explains possible solutions or answer to other students.</td>
<td>• Focus students’ attention on a particular aspect of their engagement and exploration experiences, and provide opportunities to demonstrate their conceptual understanding, process skills or behaviours. This phase also provides opportunities for teachers to introduce a concept, process or skill.</td>
<td>• Formally provides definitions, explanations and new vocabulary.</td>
</tr>
<tr>
<td>• Listen critically to other students’ explanations.</td>
<td>• Connect: prior knowledge and background to new discoveries.</td>
<td>• Uses students’ previous experiences as the basis for explaining concepts.</td>
</tr>
<tr>
<td>• Questions other students’ explanations.</td>
<td>• Communicate new understandings.</td>
<td>• Encourages students to explain their observations and findings in their own words.</td>
</tr>
<tr>
<td>• Listens to and tries to comprehend explanations offered by the teacher.</td>
<td>• Connect: informal language to formal language.</td>
<td>• Provides definitions, new words and explanations.</td>
</tr>
<tr>
<td>• Refers to previous activities.</td>
<td></td>
<td>• Listens and build upon discussion from students.</td>
</tr>
<tr>
<td>• Uses recorded observations in explanations.</td>
<td></td>
<td>• Asks for clarification and justification.</td>
</tr>
<tr>
<td>• Uses previous observations and findings.</td>
<td></td>
<td>• Accepts all reasonable responses.</td>
</tr>
<tr>
<td>• Provides reasonable responses to questions.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Elaboration**

This phase of the teaching model challenges and extends students’ conceptual understanding and allows further opportunity for students to practice desired skills and behaviours. Through new, experiences, the students develop deeper and broader understanding, more information, and adequate skills.

Table 1.4

The Students and Teachers Activities during Elaboration phase of 5 ‘E’ model

<table>
<thead>
<tr>
<th>The Student…</th>
<th>Explain activities</th>
<th>The Teacher…</th>
</tr>
</thead>
</table>
| • Applies new labels, definitions, explanations, and skills in new, but similar, situations.  
• Uses previous information to ask questions, proper solutions, make decisions, design experiments.  
• Draws reasonable conclusions and solutions.  
• Record observations, explanations, and solutions. | • Challenge and extend students’ conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills.  
• Apply new learning to a new or similar situation.  
• Extend and explain concept being explored, communicate new understanding with formal language. | • Expects student to use vocabulary, definitions, and explanation provided previously in new context.  
• Encourages students to apply the concepts and skills to new situations.  
• Reminds and refers students of alternative explanations.  
• Uses previously learned information as a vehicle to enhance additional learning.  
• Encourages students to apply or extend the new concepts and skills. Encourages students to use terms and definitions previously acquired. |
Evaluation

This phase of the teaching model encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Table 1.5

The Students and Teachers Activities during Evaluation phase of 5 ‘E’ model

<table>
<thead>
<tr>
<th>The Student…</th>
<th>Explain activities</th>
<th>The Teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Demonstrates an understanding or knowledge of concepts and skills.</td>
<td>• Encourage students to assess their understanding and abilities and provide opportunities for teachers to evaluate student progress.</td>
<td>• Assesses students’ knowledge and skills.</td>
</tr>
<tr>
<td>• Answers open-ended questions by using observations, evidence, and previously accepted explanations.</td>
<td>• Demonstrate understanding of new concept by observation and open-ended response.</td>
<td>• Observe students as they apply new concepts and skills.</td>
</tr>
<tr>
<td>• Evaluates his or her own progress and knowledge.</td>
<td>• Apply within problem situation.</td>
<td>• Looks for evidence that students have changed their thinking.</td>
</tr>
<tr>
<td>• Asks related questions that would encourage future investigations.</td>
<td>• Show evidence of accomplishment.</td>
<td>• Allows students to assess their learning and group process skills.</td>
</tr>
<tr>
<td>• Provides reasonable responses and explanations to events or phenomena.</td>
<td></td>
<td>• Asks open-ended questions such as Why do you think…? What evidences do you have? What do you know about the problem? How would you answer the question?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Encourages students to assess their own learning.</td>
</tr>
</tbody>
</table>

Bybee & et al. (1993) did various experiment in biology subject when they were developing the curriculum for biology. They found constructivist 5 ‘E’ model is very useful model in learning biology as well as science.
1.2.20 Science education

The common aim of all science education researchers is to help students learn science subjects in the most appropriate way. There have been many investigations in science teaching strategies and curriculum development in order to improve the effectiveness of science teaching. In the last two decades, educators have emphasized the constructivist approach in teaching science (Tobin, 1990; Trumper, 1997). The constructivist view is a very powerful and influential perspective to many science education research studies.

Much of the research appearing in science education journals over the past decade has focused on two broad areas: curriculum change in science education and the use of multiple instructional strategies to improve learning (Hurd, 2002; Kelly & Anderson, 2000).

There is strong consensus among science educators that multiple approaches to learning are necessary to improve overall science achievement (Anderson & Hogan, 2000). These include tested instructional practices, collaborative support involving communities of learners, and the use of technology to enrich the learning environment. Effective science instruction must not only increase learning, but also help students develop the metacognitive lifelong learning skills needed to succeed at higher levels of science, and to reconstruct their conceptual knowledge and procedural strategies when necessary. In addition, effective instruction should help students and teachers become aware of the beliefs they hold about science that affect their learning, or in the case of teachers, affect their curricular and pedagogical decisions.

Based on a review of selected science education journals over the past decade Schraw, Crippen and Hartley (2006) identified six general areas of instructional strategies for improving science learning. They summarize research in each of the six strategic areas and discuss how these instructional interventions relate to metacognition and self-regulation. These areas are, (a) inquiry based learning, (b) the role of collaborative support, (c) strategy instruction to improve problem solving and critical thinking, (d) strategies for helping students construct mental models and to experience conceptual change, (e) the use of technology, and (f) the impact of student and teacher beliefs. Each of these six areas has been shown to improve metacognitive awareness and self-regulation.
Numerous research studies have been conducted using constructivist practices in teacher education programs. Constructivist ideas applied to teaching have become a staple content area within many teacher education programs.

1.2.21 Teacher education

Constructivists present several useful tenets to teacher educators and individuals who are being educated to be teachers. First, the learner is active in creating meaning. Second, the traditional roles of passive learner and teacher-as-spoon-feeder must be reconsidered, with increasing responsibility recognized for and by the learner. Third (at least in some versions of constructivism), the learner goes through a series of broad stages of learning in which, describable mental activities occurs.

Fosnot (1996) argues that the primary goal of a constructivist approach to teacher education is to facilitate new ways of knowing. If understanding the teaching/learning process from a constructivist view is itself constructed, and if teachers tend to teach as they were taught, rather than as they were taught to teach, then teacher education needs to begin with these traditional beliefs and subsequently challenge them through activity, reflection, and discourse in both coursework and field work through the duration of the program. Most importantly, participants need experiences as learners that confront traditional views of teaching and learning in order to enable them to construct a pedagogy that stands in contrast to older, more traditionally held views.

The issue of teacher metacognition is often not addressed explicitly in the literature. This is not too surprising because the majority of research conducted in relation to metacognition focuses on school students’ thinking and learning processes. However, with an increased emphasis on the development of students’ learning processes it would seem obvious that teachers would need to be in touch with their knowledge, control and awareness of their own thinking and learning processes, especially in relation to cognitive processes related to reform initiatives that call for the development of students’ higher order thinking. This would seem to be a necessary condition for them to serve as cognitive and metacognitive role models for their students. Teachers who are aware of their own metacognitive functioning tend to play a more significant role in helping learners develop skills in metacognition (Sternberg, 1998).
1.3 Rationale

In recent years, metacognition is regarded as an important component of learning in the sciences. The following are a sample of reasons suggested by the literature for this:

(1) In many research studies in the area of science teaching it was found that metacognitive processes promote meaningful learning, or learning with understanding (Thomas & McRobbie, 2001; Davidowitz & Rollnick, 2003). Meaningful learning, which, as a result of it students improve their ability to apply what they have learned in a new context, is one of the goals of teaching (Kuhn, 1999). Most of these researchers suggest that one of the main characteristics of meaningful learning is the student’s ability to control a problem-solving process and the performances of other learning assignments. These researchers link this control to the student’s awareness of his/her physical and cognitive actions during the performance of a certain task.

(2) In view of a constantly changing technological world when, not only is it impossible for individuals to acquire all existing knowledge, but it is also difficult to envisage what knowledge will be essential for the future (Georghiades, 2004). The development of metacognitive abilities that will enable the student to study any desirable knowledge in the future becomes essential.

(3) One of the goals of science education is the development of an independent learner (NRC, 1996; 2005). Efficient independent learning requires the learner to be aware and in control of his/her knowledge and of the options to expand it. This means in other words that the student must utilize and develop metacognitive skills.

Relating metacognition to developing one’s self-knowledge and ability to ‘learn how to learn’ resulted in metacognition being awarded a high status as a feature of learning. The subsequent calling for inclusion of metacognition in the development of school curricula, therefore, seems fully justified. Flavell (1987) proposed that good schools should be ‘hotbeds of metacognitive development’ because of the opportunities they offer for self-conscious learning. Similarly, Paris and Winograd (1990) have argued that students’ learning can be enhanced by becoming aware of their own thinking as they read, write, and solve problems in school, and that teachers should promote this awareness directly by informing their students about effective problem-solving strategies and discussing cognitive and motivational characteristics of thinking. Clearly sharing this view, Gunstone and Northfield (1994) took a step
further and argued in favour of a central position of metacognitive instruction within teacher education. Borkowski and Muthukrishna (1992) similarly have argued that metacognitive theory has considerable potential for aiding teachers in their efforts to construct classroom environments that focus on flexible and creative strategic learning. Voices advocating the importance of metacognitive activity within educational contexts have resulted in placing metacognition high on educational research agendas.

If one is interested in enhancing science teaching and learning, it seems only reasonable to begin with an understanding of how students learn science. Several decades of research in the cognitive and developmental sciences have built a knowledge base that curriculum developers can use. This research has been synthesized by the National Research Council (NRC) and described in several publications, *How People Learn: Brain, Mind, Experience, and School* (Bransford, Brown, & Cocking, 1999), *Knowing What Students Know* (Pellegrino, Chudowsky, & Glaser, 2001), and *How Students Learn: Science in the Classroom* (Donovan & Bransford, 2005). Three principles of learning from this body of knowledge establish the basis for curriculum and instruction. 1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom. 2. To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. 3. A ‘metacognitive’ approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving those (Donovan & Bransford, 2005).

Above findings tells us that a ‘metacognitive’ approach to instruction presents an additional element to the design of instructional materials. Martinez (2006) recently elaborated on this aspect of student learning. Going beyond the introductory definition of metacognition as ‘thinking about thinking’, Martinez proposed the definition ‘monitoring and control of thought’ and the specific function of metamemory and metacomprehension, problem solving, and critical thinking. Martinez suggests three ways of introducing metacognitive strategies in science teaching and curricula. First is an obvious recommendation – students must have experiences that
require metacognition. Second, teachers should model metacognitive strategies by ‘thinking aloud’ problem solving and inquiry based activities. Finally, students should have opportunities to interact with other students. This suggests the need for group work and an inquiry-oriented approach to the science curriculum which may develop metacognitive skills.

Looking into this conceptual framework researcher came to the conclusion that there are research evidences available which suggest the relation between the metacognition and constructivism. But strong evidences are not available which suggest which among the two work as a cause and other as effect. After studying the constructivist 5 ‘E’ model researcher decided to study the development of metacognitive skills in science student-teachers through constructivist approach using constructivist 5’E’ model. Hence researcher conducted this study to investigate answer of the following questions:

1.4 Research Questions

The main goal of the research was to investigate the potential of the constructivist 5 ‘E’ model for developing metacognitive skills among science student teachers. More specifically, the two research questions were:

1. Does the constructivist approach in particular 5 ‘E’ model provide opportunities for developing metacognitive skills and in which stages of the 5 ‘E’ model do those skills find expression?

2. What are the metacognitive characteristics that find expression in the various 5 ‘E’ model stages?

1.5 Statement of the Problem

The statement of the problem was formulated as below.

Development of Metacognitive Skills in Science Student-Teachers through Constructivist Approach

1.6 Objectives of the Study

The objectives of the study were:

1. To study the development of metacognitive knowledge in science student-teachers while learning science through constructivist (5 ‘E’ model) approach.

2. To study the development of metacognitive regulation in science student-teachers while learning science through constructivist (5 ‘E’ model) approach.
1.7 Hypotheses

The following hypotheses were tested to know the development of metacognitive knowledge, metacognitive regulation and metacognitive skills among science student-teachers through constructivist (5 ‘E’ model) approach.

H₀₁ There will be no significant difference between the pre-test score and post-test score of declarative knowledge in science student-teachers.

H₀₂ There will be no significant difference between the pre-test score and post-test score of procedural knowledge in science student-teachers.

H₀₃ There will be no significant difference between the pre-test score and post-test score of conditional knowledge in science student-teachers.

H₀₄ There will be no significant difference between the pre-test score and post-test score of metacognitive knowledge in science student-teachers.

H₀₅ There will be no significant difference between the pre-test score and post-test score of planning skills in science student-teachers.

H₀₆ There will be no significant difference between the pre-test score and post-test score of monitoring skills in science student-teachers.

H₀₇ There will be no significant difference between the pre-test score and post-test score of evaluating skills in science student-teachers.

H₀₈ There will be no significant difference between the pre-test score and post-test score of metacognitive regulation in science student-teachers.

H₀₉ There will be no significant difference between the pre-test score and post-test score of metacognitive skills in science student-teachers.

1.8 Operational Definition of Terms

Following important terms involved in the study were operationalised as below:

1.8.1 Metacognitive skills

Metacognitive skill includes two main component metacognitive knowledge and metacognitive regulation.

1. Knowledge of cognition refers to what individuals know about their own cognition or about cognition in general. It includes declarative, procedural and conditional knowledge (Schraw, 1998) or personnel, task and strategy knowledge Flavell et al. (2002).

Declarative knowledge includes knowledge about oneself as a learner and about factors that influence one’s performance (knowing ‘about’ things).
Procedural knowledge refers to knowledge about doing things. Much of this knowledge is represented as heuristics and strategies (knowing ‘how’ to do things).

Conditional knowledge refers to knowing when and why to use declarative and procedural knowledge (knowing the ‘why’ and ‘when’ aspects of cognition).

*Knowledge of person variables*—refers to knowledge about how human beings learn and process information, as well as individual knowledge of one’s own learning processes.

*Knowledge of task variables*—includes knowledge about the nature of particular tasks or more generalized knowledge about types of task as well as the processing demands that will be placed upon the individual.

*Knowledge about strategy*—variables include knowledge about both cognitive and metacognitive strategies, as well as conditional (contextual knowledge) about when and where it is appropriate to use such strategies.

2. *Regulation of cognition* refers to a set of activities that help students control their learning. Although a number of regulatory skills have been described in the literature, three essential skills are included in all accounts: planning, monitoring, and evaluation.

Planning involves the selection of appropriate strategies and the allocation of resources that affect performance.

Monitoring refers to one’s on-line awareness of comprehension and task performance.

Evaluating refers to appraising the products and efficiency of one’s learning.

Students possessing these qualities which can be manifested and demonstrated through observation and interview will indicate the possession of metacognitive skills.

Schraw (1998) model was used to analyze data obtained through observation and Flavell et al. (2002) model was used to analyze data obtained through interview and reflective essay.

Apart from these qualitative aspects the score obtained by student-teachers on the metacognitive skill inventory represent metacognitive skills. The each component score was calculated separately which represent that particular skill. The total of the entire components was considered the score of metacognitive skill.

All these behaviours manifested during the learning science through constructivist approach were considered as metacognitive skills.
1.8.2 Constructivist Approach

For the present study constructivist approach means using 5 ‘E’ model that is following the each step of this model engage, explore, explain, elaborate and evaluate. The students are followed through the lesson plan drawn based on 5 ‘E’ model.

1.9 Delimitation of the Study

The study was delimited in terms of following criteria.

1. The study is delimited to the science student-teachers studying in B.Ed. colleges of Gujarati medium.

2. This study includes two models of metacognition given by Schraw (1998) and Flavell et al. (2002) respectively.