CHAPTER –II

CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter attempts how concepts of metacognition are developed to enhance achievement in physics. It works on the presentation of detailed conceptual analysis of the Flavell and Brown model of metacognition, teaching and learning in metacognitive environment, implementation of metacognitive strategies and development of a metacognitive model for achievement in physics at higher secondary level – A model generation.

2.2 Cognitive processes

Cognition, which refers to the higher processes involved in understanding and dealing with the world around us in the foundation on which all the experiences of the child have to be built(Galotti M.K.(2007), Carrer,M.S(2001)). Cognition can be defined as the processing of information about the environment that is received through the senses. Cognition refers to mental activity and behavior through which knowledge of the world is attained and processed including perception, memory and thinking.

Cognitive processes are unobservable mental actions used to manipulate information. Cognitive processes produce cognitive products and it may be processed again, or they may be manifested in performance. Cognitive processing can be applied to any kind of information. Students' cognitive systems have the potential to process not only the various kinds of information found in educational curricula, but also information that teachers provide to students to help them achieve
the educational objectives. Cognition is both an effect caused by previous events, including cognitive ones and a cause of future events. Students' cognitive processing during teaching consists of reciprocal interactions among their cognitive processing system on the one hand, and the curriculum and instructional cues on the other. If students were exposed to curricular information devoid of instructional cues that is without instruction they almost surely would learn something. The intent of supplementing curricula with instruction is to improve the quality of students' cognitive processing beyond their natural levels. Thus, the objective of teaching is to influence the cognitive processing students use to learn.

2.3 Metacognition

According to the "The Blackwell dictionary of cognitive psychology", metacognition may be defined as "knowledge or belief about one's own cognitive processes". This knowledge may also be used in the regulation of cognitive activities.

According to Flavell, J.H. (1976), Metacognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact.—Flavell, J.H. (1976, p. 232)

Brown(1987) defined metacognition as the knowledge and awareness one has of his own thinking processes and strategies and the ability to evaluate and regulate one’s own thinking processes. It is learning to think about the how and why of what one does.
Metacognition is defined as "cognition about cognition", or "knowing about knowing." - Schraw and Dennison (1994)

"Metacognition" is defined as "thinking about thinking."
- Livingston (1997)

Pintrich (2004) defines metacognition as “an appreciation of what one already knows, together with a correct apprehension of the learning task and what knowledge and skills it requires, combined with the ability to make correct inferences about how to apply one’s strategic knowledge to a particular situation, and to do so efficiently and reliably.”

Metacognition refers to higher order thinking which involves active control over the cognitive processes engaged in learning. Activities such as planning how to approach a given learning task, monitoring comprehension, and evaluating progress toward the completion of a task are metacognitive in nature.

Metacognition involves two major dimensions. Firstly, it involves an awareness of one’s own cognitive functioning (metacognitive knowledge) and secondly, application of one’s cognitive resources for learning or problem-solving – Boekaerts,(1999)


Tobias and Everson (1998) suggest that “knowledge of cognition is a prerequisite to regulation of cognition” and that those with high knowledge of cognition were more likely to demonstrate greater regulation of cognition.

Emrri.(2009) suggests that metacognitive knowledge and intellectual aptitude are unrelated and that metacognitive skills help
children of lower aptitude compensate on problem-solving tasks. Research on college students with learning disabilities also suggests that metacognition and self-regulated behavior is a strong predictor of academic success.

2.4 Models of metacognition

A number of models have been proposed from different conceptualization of metacognition. The models proposed by Flavell (1979) and Brown (1987) explain the metacognitive knowledge and metacognitive experience well. The models of Flavell and Brown can be used as good guides for readers to understand and conceptualize the components of metacognition. The metacognitive skills suggested by Flavell and Brown should be useful in a number of fields and not only in the field in which they were initially trained, since they are general rather than specific.

John Flavell (1979) of Stanford University is regarded as foundation researcher in metacognition. The first attempt to generate a formal model of metacognition was presented by Flavell. He acknowledged the significance of metacognition in a wide range of applications which included reading, oral skills, writing, language acquisition, memory, attention, social interactions, self-instruction, personality development and education.

Flavell used the term metamemory in regard to an individual's ability to manage and monitor the input, storage, search and retrieval of the contents of his own memory. He implied with his statements that metacognition is intentional, conscious, foresighted, purposeful, and directed at accomplishing a goal or outcome. In his 1976 article, Flavell recognized that metacognition consisted of both monitoring and regulation aspects.
Fig. 2.1 John Flavell model of metacognition

He defined metacognition as follows: "In any kind of cognitive transaction with the human or non-human environment, a variety of information processing activities may go on. Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective."

Flavell (1976) also identified three “metas” that children gradually acquire in the context of information storage and retrieval. These were:

(a) The child learns to identify situations in which intentional, conscious storage of certain information may be useful at some time in the future
(b) The child learns to keep any current information which may be related to active problem-solving, and have it ready to retrieve as needed and

(c) The child learns how to make deliberate systematic searches for information which may be helpful in solving a problem, even when the need for it has not been foreseen.

In this work Flavell acknowledged the explosion of interest and work in areas related to metacognition, such as oral skills of communication, persuasion and comprehension, reading, writing, language acquisition, memory, attention, problem-solving, social cognition, affective monitoring, and self-instruction.

Flavell mentioned that components of metacognition can be activated intentionally, as by a memory search aimed at retrieving specific information, or unintentionally, such as by cues in a task situation. Metacognitive processes can operate consciously or unconsciously and they can be accurate or inaccurate. They can also fail to be activated when needed, and can fail to have adaptive or beneficial effect.

Metacognition can lead to selection, evaluation, revision or deletion of cognitive tasks, goals, and strategies. They can also help the individual make meaning and discover behavioral implications of metacognitive experiences.

In his 1979 paper, Flavell proposed a formal model of metacognitive monitoring which included four classes of phenomena and their relationships. The four classes were
The first of Flavell's (1979) class was metacognitive knowledge, which he defined as one's knowledge or beliefs about the factors that effect cognitive activities. The distinction between cognitive and metacognitive knowledge may lie in how the information is used, more than a fundamental difference in processes. Metacognitive activity usually precedes and follows cognitive activity. They are closely interrelated and mutually dependent. Metacognitive knowledge can lead the individual to engage in or abandon a particular cognitive enterprise based on its relationship to his interests, abilities and goals. Flavell described three categories of these knowledge factors:

i. Person variables  
ii. task variables  
iii. strategy variables

These are the three categories in which Flavell proposed that individuals have metacognitive knowledge.

The person category of knowledge includes the individual's knowledge and beliefs about himself as a thinker or learner, and what he believes about other people's thinking processes. Flavell gave examples of knowledge such as a person believing that he can learn better by listening than by reading, or that a person perceives her friend to be more socially aware than she is. One's beliefs about himself as a learner may facilitate or impede performance in learning situations.
The task category of metacognitive knowledge encompassed all the information about a proposed task that is available to a person (Flavell, 1979). This knowledge guides the individual in the management of a task, and provides information about the degree of success that he is likely to produce. Task information can be plentiful or scarce, familiar or unfamiliar, reliable or unreliable, interesting or not, organized in a useable or unusable fashion. Task knowledge informs the person of the range of possible acceptable outcomes of the cognitive enterprise and the goals related to its completion. Knowledge about task difficulty and mental or tangible resources necessary for its completion also belong to this category.

The strategy category of metacognitive knowledge involved identifying goals and sub-goals and selection of cognitive processes to use in their achievement (Flavell, 1979). Flavell also emphasized that these types of variables overlap and the individual actually works with combinations and interactions of the metacognitive knowledge that is available at that particular time. He also stated that metacognitive knowledge is not fundamentally different than other knowledge, but its object is different. He also mentioned that metacognitive knowledge may be activated consciously or unconsciously by the individual. This question of consciousness later became a subject of controversy among researchers in metacognition.

Metacognitive experiences, Flavell's (1979) second class of phenomena included the subjective internal responses of an individual to his own metacognitive knowledge, goals, or strategies. These may be fleeting or lengthy, and can occur before, during, or after a cognitive enterprise. As monitoring phenomena, these experiences can provide internal feedback about current progress, future expectations of progress
or completion, degree of comprehension, connecting new information to old, and many other events. New or difficult tasks, or tasks performed under stress tend to provoke more experiential interaction, while familiar tasks may tend to provoke less metacognitive experience.

According to Flavell (1979), metacognitive experience can also be a “stream of consciousness” process in which other information, memories, or earlier experiences may be recalled as resources in the process of solving a current-moment cognitive problem. Metacognitive experience also encompasses the affective response to tasks. Success or failure, frustration or satisfaction, and many other responses effect the moment-to-moment unfolding of a task for an individual, and may in fact determine his interest or willingness to pursue similar tasks in the future. Flavell underscored the overlapping nature of metacognitive knowledge and metacognitive experience.

Metacognitive goals and tasks are the desired outcomes or objectives of a cognitive venture. This was Flavell's third major category. Goals and tasks include comprehension, committing facts to memory, or producing something, such as a written document or an answer to a math problem, or of simply improving one's knowledge about something. Achievement of a goal draws heavily on both metacognitive knowledge and metacognitive experience for its successful completion (Flavell, 1979).

Metacognitive strategies are designed to monitor cognitive progress. Metacognitive strategies are ordered processes used to control one's own cognitive activities and to ensure that a cognitive goal (for example, solving a math problem, writing an effective sentence, and understanding reading material) has been met. A person with good
metacognitive skills and awareness uses these processes to oversee his own learning process, plan and monitor ongoing cognitive activities, and to compare cognitive outcomes with internal or external standards. Flavell (1979) indicated that a single strategy can be invoked for either cognitive or metacognitive purposes and to move toward goals in the cognitive or metacognitive domains. He gave the example of asking oneself questions at the end of a learning unit with the aim of improving knowledge of the content, or to monitor comprehension and assessment of the new knowledge.

**Brown’s model of metacognition**

Brown (1987) divides metacognition into two broad categories: (1) knowledge of cognition, as activities that involve *conscious* reflection on ones cognitive abilities and activities; and (2) regulation of cognition, as activities regarding self-regulatory mechanisms during an ongoing attempt to learn or solve problems. According to Brown, these two forms of metacognition are closely related, each feeding on the other recursively, although they can be readily distinguishable.

![Metacognition Diagram](image)

**Fig 2.2 Brown's model of metacognition**

**Knowledge about cognition** refers to the stable, statable, often fallible, and often late developing information that human thinkers have about their own cognitive processes as it requires that learners step back and consider their own cognitive processes as object of thought and
reflection; traditionally this has been referred to as *knowing that* (Brown, 1987).

**Regulation of cognition** consists of the activities used to regulate and oversee learning. These processes include planning activities (predicting outcomes, scheduling strategies, and various forms of vicarious trial and error, etc) prior to undertaking a problem; monitoring activities (monitoring, testing, revising, and re-scheduling one’s strategies for learning) during learning; and checking outcomes (evaluating the outcome of any strategic actions against criteria of efficiency and effectiveness). It has been assumed that these activities are relatively unstable (although they are ubiquitously employed by adults on simple problems), not necessary statable (knowing how to do something does not necessarily mean that the activities can be brought to the level of conscious awareness and reported on to others), and relatively age independent (i.e., task and situation dependent). Additionally, Brown introduced the concept of “autopilot state”, arguing that expert learners (e.g. readers) monitor their comprehension and retention and evaluate their own progress in the light of the purposes for which they are learning to the extent that these activities become automatic and learners proceed as if in “automatic pilot”. This concept tries to explain why metacognitive learners (i.e. those who apply metacognitive knowledge and skills in learning situations) sometimes are not conscious of their strategies and cannot describe their metacognitive knowledge. This model emphasizes the *executive processes*, stressing the importance of the *control* that people bring or fail to bring to cognitive endeavors. Moreover, Brown points to important characteristics of regulation of cognition, that has to be taken into account for those interested in the applications of these concepts into instructional research.
2.5 Teaching and learning physics in a metacognitive environment

From the two decades of research, the trend in studies of Physics learning seems to have focused on cognition and subsequently metacognition. Young and Jane (2008) through their framework of Physics teaching, argue that Physics education has shifted from the dimension of cognition in the 2000 to that of metacognition in the 2005. The abstract nature of Physics necessitates that its concepts and principles be learned in an environment where students can meaningfully grasp the material to be studied. Students must be given opportunities to make use of their prior knowledge in order to construct new ones. Students must be able to discuss, negotiate and defend their solutions to problems in small group settings. If these are consistently done in the Physics classroom, then, meaningful learning will most likely occur. One promising way by which students can achieve meaningful learning is by letting them engage in academic tasks designed in a constructivist environment. Constructivism is a philosophy which espouses that students must be actively engaged in their knowledge construction. Constructivism asserts that knowledge is not passively received but is actively built up by the learner (Amignes R (1988)). In the past decade, the learning of Physics has been investigated using constructivist lens; researchers have explored the study of physical phenomena using constructivist principles. These researchers rationalize that constructivism is the philosophical and pedagogical bases in the learning and teaching of Physics (Chi.et.al(1981), Coleman et.al.(1997), King (1992)). Opportunities for students to engage in reflective abstractions, where they deliberately stop and reflect on their thinking processes, how they plan and execute academic tasks, and how they solve problems, is consistent with a constructivist philosophy. These activities are best accomplished in small
group settings (Amigues R(1988)) and when students think about their own thinking, cognition and metacognition come into play (Ganz M N et.al.(1990)). Most researchers and theorists describe metacognition, or a metacognitive system, as a series of thought processes responsible for monitoring, evaluating and regulating functioning. These functions are sometimes referred to as executive control. According to Pintrich(1992) metacognition involves three dimensions. These are knowledge about oneself, knowledge about the thinking process, and controlling of one's commitment, attitude and attention to learn new or complex tasks. Commitment is defined as a deliberate choice to adopt strategies in solving problems. The various types of knowledge important in metacognition are declarative, procedural and conditional knowledge. Declarative knowledge pertains to the facts necessary to accomplish a task, while the steps or procedures and even strategies on how a task is done fall under the domain of procedural knowledge. Conditional knowledge refers to knowing why certain strategies work, when to use them and why one strategy is better than another (Pintrich (2004)). Controlling the thinking process involves planning [choosing a path to goals, choosing procedures], regulating [checking progress, revising paths, procedures, goals and resources] and evaluating [assessing current knowledge, setting goals, and selecting resources] .Metacognition is differentiated from reflective thinking in the sense that reflective thinking is a more generalized construct, whereas being metacognitive is a deliberate reflection on one's own cognitive functioning (Veeman et.al.(2004)). Early research on metacognition explored constructs such as mind's ability to purposely store and retrieve information. Investigations pioneered by Flavell and his colleagues paved the way for further exploration of metacognition. These studies were empirical in nature and were rooted in the discipline of Cognitive Psychology.
2.6 Teaching techniques and principles adopted for implementation of metacognition

Hartman (1998) states that "teaching with metacognition means that teachers will think about their own thinking regarding instructional goals, teaching strategies, sequence, materials, students' characteristics and needs and other issues related curriculum, instruction and assessment before, during and after lessons in order to maximize their instructional effectiveness".

Hartman (2001) states that "teaching for metacognition means that teachers will think about how their instruction will activate and develop their students' metacognition".

Lin (2001) suggests that metacognitive instruction is effective only it involves theory and practice. The learner must be given some knowledge of cognitive process as well as opportunities to practice metacognitive strategies. Simply providing knowledge without experience does not seem to be sufficient for metacognitive development.

Metacognitive activities are implemented based on the following principles suggested by researchers to promote metacognition in the classroom.

**Reflective questions and reflective prompts**

Reflective questions and reflective prompts are simple ways employed by teachers and researchers to promote discussion that begins with revision of the details of the learning experience and moves toward critical thinking and creation of an action plan. This can encourage students to reflect on strategies that they use to perform a learning task (such as solving a problem) and explain their reasons for using those
strategies. There is a difference between questions and prompts. Questions are of a more general nature, serving as a way for triggering broad metacognitive monitoring. Examples of questions are: “Now what?” or “So what?” They may help the student to reflect on the next step and make links to the previous tasks done. On the other hand, reflective prompts (also called metacognitive prompts) are more focused. Questions that provide a more directive help on specific aspects of the learning processes. These prompts aim at guiding coherent understanding of the domain tasks at hand and may lead to extensive inference generation (Lin, 2001). To be effective, the prompts should use open-ended questions. For example, prompts like “Should your goals be reformed?” The prompts should ask for specifics and examples, even if it is the case that the student is not going to write down her reflections (e.g. “What is a new example of ...?”). Another prompting technique consists in paraphrasing and summarizing what the student says when she asks for help; for example: “So what you are concerned about is how you can monitor your problem solving attempt?” Finally, prompts can also redirect questions to learner, like “Note taking is not occurring in your study from text, should that be the goal of this stage?” Prompting has also been used to stimulate self-explanation for metacognitive development-eliciting learners’ explanations and justifications through prompting can help them to draw conclusions and make inferences that can lead to increased comprehension (Chi et al., 1989). Lin and Lehman (1999) conducted a study to see whether different instructional prompts could help students reflect on their understanding of variable control in a biology-based computer environment. Results of the study indicated that students who received metacognitive prompts outperformed the other groups on a far-transfer problem. Similar results have been obtained in different domains such as maths and science and different tasks, such as
learning from expository text (Chi et al., 1989). The difficulty is to detect the adequate moment to interrupt the student to prompt her to reflect on what she is doing or why she is doing it. Good teachers know when to step in and ask appropriate questions and when to stand back and let the learner figure things out for herself.

**Metacognitive scaffolding**

Scaffolding means providing support to students to bridge the gap between what they can do on their own and what they can do with guidance from others (Hartman, 2001). Scaffolding may take the format of models, cues, prompts, hints, partial solutions, etc. The main characteristic of scaffolds is that they have to be regulated according to the amount of help the learner needs, and eventually the help should be not necessary anymore. Metacognitive scaffolds support the underlying processes associated with individual learning management, providing guidance in how to think during learning. It might remind learners to reflect on the goal(s) or prompt them to relate the use of a given resource or tool to the completion of a task at hand. The scaffolding is intended to serve as an external model of knowledge monitoring behaviour until it is internalized. Therefore, the goal of metacognitive scaffolding is for students to become independent, self-regulating thinkers who are more self-sufficient and less teacher-dependent. It is an especially effective teaching approach for developing higher level cognitive strategies (Hartman, 2001). There are two types of metacognitive scaffolding: it can be either domain-specific or more generic. When the problem context is known, scaffolding can emphasize specific ways to think about the problem. In contrast, generic scaffolding focuses on the processes of creating models. This includes finding ways to link models with prior knowledge and experience, linking representational models to current
understanding, and enabling learners to manipulate ideas through modeling tools (Hartman, 2001).

**Self-questioning**

Self-questioning strategies are effective ways of promoting self-directed learners. Research on self-questioning shows that questions created by the student are much more effective than questions given to the student by someone else. Self-questions such as “Have I left out anything important?” can help a student self-direct in identifying the omission of important points or examples. The more students practice generating and using self-questions in diverse situations the more likely they are to develop the habit of self-questioning so that it becomes a skill, which is used automatically and unconsciously as the situation requires. It is important to regularly have students adapt their self-questions to the needs of the specific subject and task. Self-questioning can guide the learner’s performance before, during, and after task performance; it can improve self-awareness and control over thinking and thereby improve performance; self-questioning can improve long-term retention of knowledge and skills; it can improve the ability to apply and transfer knowledge and skills students learn; and finally, it can improve attitudes and motivation as a result of improved performance (Hartman, 2001). Lin (2001) believes that knowledge monitoring is a valuable skill that should be fostered in students. She argues that, by identifying what they know and do not know, students can focus their attention and resources more appropriately.

Zimmerman (1998) adds that, by knowing what they already know, students become aware of the potential knowledge and skills that they can bring to bear, which boosts their confidence in their own learning. Tobias and Everson believe that knowledge monitoring is
central to learning from instruction in varied domains. They have conducted 23 experiments that support the importance of accurate monitoring of prior knowledge in students’ strategic behaviour during learning. For instance, one of their experiments demonstrated that students who monitor knowledge well generally seek more help on the vocabulary they think is unknown than those not so good at monitoring. These findings were substantially confirmed in the domain of mathematics. Another experiment found that accurate knowledge monitors required less external feedback regarding the accuracy of their responses. They argue that this happens because they were able to supply their own internal feedback (Tobias and Everson, 1998). Another interesting observation is the positive correlation between knowledge monitoring and academic achievement. They argue that much of the research conducted to date supports this correlation, including their own research on the assessment of knowledge monitoring. Their earlier research, for example, indicated that knowledge monitoring ability was related to academic achievement in college (Tobias and Everson, 1998). Moreover, the relationship between knowledge monitoring and academic achievement was documented in diverse student populations, including elementary school students, students attending academically oriented high schools, vocational high school students, college freshmen, and those attending college for some time (Tobias and Everson, 1998).

**Thinking aloud and Self-explanations**

Thinking aloud is a technique of externalizing one’s thought processes as one is engaged in a task that requires thinking. The thinker says out loud all of the thoughts and feelings that occur when performing a task (e.g. solving a problem, answering a question, conducting an
experiment, reading through textbook notes, etc.). It is a method that can be used either by the teacher or tutor, or by two students working together, or by a student working alone. Teachers can use the think aloud method to serve as expert models showing students how to use metacognitive knowledge and strategies when working on a variety of tasks; for example, to let students see and hear how they plan, monitor, and evaluate their work. When the thinker-talker is the subject-matter expert, the process allows the expert to model their own thinking for students. This modeling shows how to think about the material (knowledge, skills, procedures, etc.). It lets students hear what goes on in an expert’s head when a text is read, a homework assignment is attacked, study for a test is planned, an essay is written, an error is found, or a problem is solved. Also, when modeling academic performance, it is important to intentionally make occasional mistakes, so that students can observe and become aware of them and also of strategies for recovering from them and self-correcting (Hartman, 2001). Lin(2002) state that think-aloud modeling may be in the form of self-questions (e.g. “Did I carefully check my work?”) or self-instructional directive statements (e.g. “That’s not what I expected. I’ll have to retrace my path”). They recommend that teachers use think-aloud modeling for showing students how to: summarize, access prior knowledge, self-monitor, obtain help, and self-reinforce. This modeling should involve communicating with students so that the lesson is an interactive dialogue instead of a monologue, and modeling should be gradually phased out as student competence and responsibility increase. Self-explanation is the process of clarifying and making more complete to oneself the content of an exercise, a text, an example, etc. Several studies in cognitive science point that students who spontaneously self-explain when they study learn more (Chi et al., (1989)). Moreover, self-explanations are usually more
effective than explanations provided by others, because they require students to actively elaborate their existing knowledge. Besides that, the student naturally addresses her specific problems in understanding the content when self-explaining, what leads to a more constructive learning. However, studies show that most students do not spontaneously engage in self-explanation and often need guidance to do it (Bielaczyc et al., (1995)) or need just to be prompted to do it (Chi et al., (1989)).

**Provide frequent opportunities for students to self-assess what they know and do not know**

Engage students in metacognitive activities that will help them to assess themselves and to explain specifically both what they know and what they do not know. By identifying what they do not know, students can focus their attention and resources toward resolving such difficulties (Bielaczyc et al., (1995); King, (1992); Lin & Lehman, (1999)). In addition, by knowing what they already know, students become aware of the potential knowledge and skills that they can bring to bear, which provides them with more confidence in learning (Lambert & McCombs, (1998); Zimmerman, (1998)). This has become a guiding principle for most strategy-training programs, particularly for domain-knowledge acquisition. For example, the 1995 study of Bielaczyc et al. used good student models to teach effective self-control strategies to help people monitor what they know and what they do not know. Other researchers used prompts to elicit self-explanations as ways to assess the understanding of a specific domain.

Developing knowledge about the self-as-learner through metacognitive activities involves helping students acquire ability for articulating their thoughts and emotions. Metacognitive strategy-training
programs that consider the self-as-learner emphasize the importance of providing students with supports for explaining and justifying their thinking (Zimmerman, (1998); Zimmerman & Kitsantas, (1999)). King’s (1992) study used guided questions to help students express where they were in the thinking and learning process. Chi et al. (1989) used prompts to help students self-explain their understanding of the science text. Bandura (1997) and Zimmerman (1998) employed social modeling to foster student ability to articulate personal goals for learning. These studies suggest that students do not spontaneously explain their thinking during the process of learning unless they are encouraged to do so. Explaining where they are in the learning process is important in making thinking explicit to other people, such as teachers, who are trying to assess student progress and provide appropriate guidance (Brown, 1997).

Ample opportunities should be provided for students to apply their knowledge flexibly across multiple contexts.

Although teachers can facilitate learning, research indicates that students must do the learning themselves. Students must also learn science content in ways that make sense to them, and their understanding of that science must be consistent with scientists’ current models for how the physical and biological world works. Classroom environments in which students are actively engaged and the instructor plays the role of learning coach (e.g., inquiry learning, cooperative group learning, hands-on activities) are helpful in achieving this goal. (Mastre, 2001)

Doing science requires not only lots of content knowledge, but also knowledge about the processes involved in scientific Implications of research on learning investigation—knowledge of the process of science.
Students should, therefore, use apparatus, objects, equipment and technology to design experiments and test hypotheses, rather than performing ‘cookbook’ labs. Just enough guidance should be provided so that students make suitable progress.

Physics is perhaps the only science in which a handful of concepts can be applied to solve problems across a wide range of contexts. Unfortunately, the transfer research literature suggests that when people acquire knowledge in one context they can seldom apply this knowledge to situations in related contexts—contexts that look superficially different from the original context, but which are related by the major idea that could be applied to solve or analyse them. The implication is that students should learn to apply major concepts in multiple contexts in order to make the knowledge ‘fluid’.

Much of the knowledge that scientists possess is referred to as ‘tacit knowledge’; it is knowledge used often but seldom made explicit or verbalized (e.g., when applying conservation of mechanical energy, one must make sure that there are no non-conservative forces doing work on the system). Tacit knowledge should be made explicit to help students recognize it, learn it and apply it. One way of making tacit knowledge explicit is by constructing qualitative arguments using the physics being learned. By both constructing qualitative arguments and evaluating others’ arguments, students can begin to appreciate the role of conceptual knowledge in ‘doing science’.

Graphic representations can be used to understand text and to solve a variety of problems. Graphic organizer techniques can help students analyze text and see how it is structured. Some graphic organizers that
can be used to understand text are flow charts, concept maps, Venn diagrams and tree diagrams. Other graphic organizers identified found to be useful for reading text: network trees, fishbone maps, cycles, spider webs, continua/scales, series of events chains, compare/contrast matrices and a problem/solution outlines. Hartman (2001) describes experiences in using a scaffolding approach to teach students how to create graphic organizers as learning strategies.

Table 2.1
Teaching techniques adopted for implementation of metacognition in research literature

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**Teaching techniques adopted in the present study**

After having gone through the various techniques suggested by the researchers, the techniques for the present study were designed by the investigator. They are inquiry based learning, cooperative learning and problem based learning.

**(i) Inquiry based learning**

The investigator conducted inquiry based learning by posing carefully drafted questions. The investigator formulated pivotal questions in advance. The students were asked to respond to these questions, which helped them to develop higher level of thinking and also draw conclusions. Additional questions were framed in terms of student responses. But pivotal questions planned in advance gave direction and thrust to the lesson and helped to accomplish the goal. The following are guidelines to conduct inquiry.
- Teacher asks questions in the students and encourages to use thumbs-up and thumbs-down to indicate whether they agree or disagree.
- Teacher asks questions, encouraging divergent thinking that leads more questions.
- Teacher is prepared for unexpected questions from the learners.
- Teacher ensures that classroom learning is focused on relevant outcomes.
- Teacher constantly alert to learning obstacles and guides learner when necessary.
- Teacher asking cross questions to articulate their own thinking.

(ii) Co-operative learning

Students are divided into 5 groups each consisting of 7 members. Each of the groups was named as learning cells. Each learning cells have at least two low achievers. High achievers in the group were allotted a single frame and she had prepared the same and taught the peers in the learning cells. The teacher explained the content coming under each frame and thus gave an overall description of the lesson.

In the next stage, the students having same frames were grouped together to discuss themselves. This was done to equalize their knowledge and understanding regarding that particular frame which they have to teach others. The student instructor teaches the allotted frame to his peer group members and the teacher supervises the study. Discussing a topic among peers and offering a solution by peers. In this method the investigator provides instructional support as students learn to do the task and then gradually shifts responsibility to the students. Here high ability and low ability students work together in groups to complete the work.
(iii) Problem based learning

In doing physics problem, teacher roams around the room to access how well the students are doing. When students are doing problems, they were guided to ask themselves the following questions towards comprehending their cognitive processes.

- What in my prior knowledge will help me with this particular task?
- In what direction do I want my thinking to take me?
- What should I do first?
- Why am I reading this selection?
- How much time do I have to complete the task?

Every student is asked to work on the problem together. Students participate with the investigator, sometimes making mistakes and having to rethink where they have been. When they are monitoring or maintaining the plan of actions they are guided to ask themselves the following questions.

- How am I doing?
- Am I on the right track?
- How should I proceed?
- What information is important to remember?
- Should I move in a different direction?
- Should I adjust the pace depending on the difficulty?
- What do I need to do if I don't understand?
- Always ask questions to herself to stay focus to the problem.
- Talking actively to herself
- Read and reread the problem for better understanding

After the problem is completed by the student, they are directed to evaluate the plan of action by asking themselves the following questions.
- How well did I do?
- Did my particular course of thinking produce more or less than I had expected?
- What could I have done differently?
- How might I apply this line of thinking to other problems?
- Do I need to go back through the task to fill in any "blanks" in my understanding?
- Monitor the progress of solution
- Check the solution after finish answering
- Check answer, equations and calculation steps.

Such an approach exposes them to the process of thinking about the way a problem is being/could be solved; when they thus reflect on or talk about the process of problem solving, metacognition mediates towards enhancing physics problem solving competency.

**2.7 Development of a metacognitive model on enhancing achievement in physics at higher secondary level – A model generation**

According to Chauhan S.S (1997) the essential characteristic of a model is the proposed structure of the model which is used to investigate the interrelationship between the variables. Research in education is concerned with the action of many factors, simultaneously or in a casual sequence in a problematic salutation. Thus it is essential that research in the field of education should increasingly make use of models in the course of its inquiries. A useful model should fulfill the following requirements.
- A model should contain structural relationship rather than associative relationship.
- A model should lead to the prediction of consequences that can be verified by observation.
- The structure of a model will desirably recall something of the causal mechanisms which are involved in the subject matter being investigated. Thus the model may contribute not only to prediction but also to explanation.
- It should become an aid to the imagination in the formulation of new concepts and new relationship and thus be the extension of inquiry.

To identify the components for metacognition, investigator has attempted to conceptualize various theories and concepts on metacognition theorized and studied by various researchers. The theories and concepts are tabulated from which the investigator has identified the components for metacognition.

**Table 2.2**

**Theories and concepts on Metacognition**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Theories/Concepts</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 Flavell</td>
<td>Metamemory, metaattention, Metalanguage, Metareading</td>
<td>Metamemory, metaattention, Metalanguage, Metareading</td>
</tr>
<tr>
<td>1979 Flavell</td>
<td>Metaknowledge – what know one knows</td>
<td>Metaknowledge, Metaplanning, Metaexperience, Metatask</td>
</tr>
<tr>
<td>1983 Armbruster*</td>
<td>Meta planning – what one is currently doing</td>
<td></td>
</tr>
<tr>
<td>1983 Armbruster*</td>
<td>Metaexperience – what one's current</td>
<td></td>
</tr>
<tr>
<td>1983 Armbruster*</td>
<td>Meta task – task to be performed</td>
<td></td>
</tr>
<tr>
<td>1985 Schoenfeld*</td>
<td>It relates 4 variables, tasks, strategies, textual features of language materials which influence comprehension memory</td>
<td>Text, tasks, strategies, comprehension memory</td>
</tr>
<tr>
<td>1985 Schoenfeld*</td>
<td>Manager or coach of a person's language, it processing and monitors the effectiveness of</td>
<td>Predictions, Performance memory,</td>
</tr>
<tr>
<td>Year</td>
<td>Author</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>1986</td>
<td>Bandura*</td>
<td>To facilitate learning, it is believed that students must develop the will or motivation to be self-regulated by realizing that they are responsible and capable of their own self-development and self-determination. This sense of personal agency for learning is gained through enhanced metacognitive process and produces in the learner a sense of self-efficacy which enhances and experiences of competency. Perceived self-efficacy-judgements of how well one can organize his cognitive behavioral skills.</td>
</tr>
<tr>
<td>1987</td>
<td>Brown</td>
<td>Monitoring, regulation and orchestration can take the form of checking, planning, selecting and inferring, self-interrogation, introspection, interpretation of ongoing experience or simply making judgements about what one knows or does not know to accomplish a task.</td>
</tr>
<tr>
<td>1998</td>
<td>Carr.et.al</td>
<td>Focus on what the child is thinking  Focus on how the child is thinking  Focus on child's thinking about own thinking</td>
</tr>
<tr>
<td>Year</td>
<td>Author(s)</td>
<td>Study Details</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>1999</td>
<td>Zimmerman et al.</td>
<td>Metacognitive activities involves attention activation, checking, planning, memory retrieval and detection of performance errors</td>
</tr>
<tr>
<td>2002</td>
<td>Lin X.D</td>
<td>Created a automatic assessment of metacognitive behaviour in integrated learning environment</td>
</tr>
<tr>
<td>2003</td>
<td>Park et al.</td>
<td>Using metacognitive prompts and messages develop task selection skills</td>
</tr>
<tr>
<td>2003</td>
<td>Ramganesh</td>
<td>Enhancing mathematical problem solving competency among teacher trainees</td>
</tr>
<tr>
<td>2004</td>
<td>Schraw G</td>
<td>Promoting metacognitive awareness through Inquiry skills</td>
</tr>
<tr>
<td>2004</td>
<td>Kramarski et al.</td>
<td>Cooperative-metacognitive instructional students were significantly outperformed</td>
</tr>
<tr>
<td>2004</td>
<td>Veeman et al.</td>
<td>To investigate the metacognitive behaviors of students in solving real world problems</td>
</tr>
<tr>
<td>2004</td>
<td>Begum J.A</td>
<td>Effect of metacognition and mediated learning experience among diet students</td>
</tr>
<tr>
<td>2006</td>
<td>Savithiri</td>
<td>Impact of metacognitive strategies in enhancing perceptual skills among high school students on learning geometry</td>
</tr>
<tr>
<td>2006</td>
<td>Balu</td>
<td>Effectiveness of metacognitive orientation among teacher trainees on developing competencies in teaching social studies</td>
</tr>
<tr>
<td>2006</td>
<td>Ponnusamy R</td>
<td>Impact of metacognitive strategies among lower achievers in history</td>
</tr>
<tr>
<td>2008</td>
<td>Young A and Jane D</td>
<td>Metacognitive awareness and academic achievement in physics among college students</td>
</tr>
<tr>
<td>Year</td>
<td>Author(s)</td>
<td>Title</td>
</tr>
<tr>
<td>------</td>
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<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>2008</td>
<td>Lin. X</td>
<td>Towards teacher's adaptive metacognition</td>
</tr>
<tr>
<td>2009</td>
<td>Ozsoy G.et.al</td>
<td>The effect of metacognitive strategy training on problem solving achievement</td>
</tr>
<tr>
<td>2010</td>
<td>Abdullah.F.A.P.B</td>
<td>To observe the patterns and metacognitive behaviour in physics problem solving</td>
</tr>
<tr>
<td>2010</td>
<td>Gulsum et.al.</td>
<td>Differences in the level of 7th-grade Turkish students' cognitive and metacognitive strategy use</td>
</tr>
</tbody>
</table>

*Referred in Ramganesh(2003)*

After having gone through the various steps and strategies suggested by various researchers, teaching techniques for achievement in physics at higher secondary level were developed by the investigator. They are inquiry based learning, cooperative learning and problem based learning. The investigator carefully identified the dimensions of metacognition. They are meta-knowledge, self-planning, self-monitoring, self-evaluation and self-regulation.
Meta-knowledge

This refers to learners' awareness of and knowledge about their memory systems and strategies for using memories effectively. The various types of knowledge important in metacognition are declarative, procedural and conditional knowledge. Declarative knowledge pertains to the facts necessary to accomplish a task, while the steps or procedures and even strategies on how a task is done fall under the domain of procedural knowledge. Conditional knowledge refers to knowing why certain strategies work, when to use them and why one strategy is better than another.

Self-planning

This refers to estimate the time required to complete the task, organize materials and study time. The following metacognitive statements improve self-planning.

- I organize my time to best accomplish my goals
- I try to break studying down into smaller steps.
- I use the organizational structure of the text to help me learn.
- What information is important to remember?
- What do I need to do if I don't understand?
- Read and reread the material for better understanding

Self-monitoring

This term refers to the learners' ability to monitor the degree to which they understand information being communicated to them, to recognize failures to comprehend, and to employ repair when failures are identified. Students were guided to ask themselves the following questions towards comprehending their cognitive processes.
- How am I doing?
- Am I on the right track?
- How should I proceed?
- Should I move in a different direction?
- Should I adjust the pace depending on the difficulty?
- Always ask questions to herself to stay focus to the problem.
- Talking actively to herself

**Self-evaluation**

This term refers to one's qualitative assessment about how well he learned the concept. Students are guided to ask the following questions.

- How well did I do?
- Did my particular course of thinking produce more or less than I had expected?
- What could I have done differently?
- How might I apply this line of thinking to other problems?

**Self-regulation**

This term refers to the learner's ability to make adjustments in their own learning processes in response to their own learning processes in response to their perception of feedback regarding their current status of learning. It also refers to accurate self assessment of what is known or not known and how to go about what is not known.

- Do I need to go back through the task to fill in any "blanks" in my understanding?
- Monitor the progress of solution
- Check the solution after finish answering
- Check answer, equations and calculation steps.

The teaching techniques and metacognitive strategies are organized to meet the demand of achievement in Physics at higher secondary level.
2.7 Conclusion

In this chapter, the investigator discussed cognitive process, models of metacognition, Teaching techniques and principles needed for metacognitive strategies, implementation of activities in the present study, and metacognitive model for achievement in physics at higher secondary level. The next chapter deals with review of related literature.