CHAPTER 1

INTRODUCTION

Historical review of Cognitive Science

Cognitive science has been regarded as a „rich scientific" discipline in one of the most standard literature on cognitive science „The Encyclopedia of Cognitive Science". It is scientific because it adopts scientific methods to study mind. It is considered rich in the sense that it has developed with contributions from various disciplines. The attempts to understand the mind by various disciplines like philosophy, psychology, neuroscience, artificial intelligence, linguistics and anthropology were already there. But their results seemed to be partial. And thus, the birth of cognitive science took place as a collaborative effort of all these disciplines to understand mind. Therefore, the history of cognitive science constitutes the relevant developments within each discipline of cognitive science along with the history of birth of cognitive science as a formal discipline in the late twentieth century. The developments in the field of cognitive science have been documented by various scholars.

Westbury & Wilensky (1998) have given a brief history of cognitive science in "Knowledge representation in cognitive science: Implications for education". However, they have mentioned that the foundations of cognitive science may be traced back to Aristotle or to the rise of scientific psychology (late 1800s and early 1900s) or more recently to the emergence of cybernetics. Nadel and Piattelli-Palmarini (2002), while writing the general introduction "What is Cognitive science" for „*The Encyclopedia of Cognitive Science*" have discussed the pre-history of cognitive science. To discuss about the cognitivism, they have presented briefly about behaviorism, against which cognitivism arose. In the modern era (after 1900), the developments in computers, cybernetics, linguistics, etc. have been discussed. Some crucial meetings, symposium, etc. have been regarded as of recent history of cognitive science, where the actual birth of cognitive science took place. Miller (2003) has presented the recent history of cognitive science and its relationship with cognitive revolution in "The cognitive revolution: a historical perspective". He also emphasized the interdisciplinary nature of cognitive science. Boden (2006) in her book, "Mind as machine: A history of cognitive science" has provided a very comprehensive history of cognitive science. She has shown how cognitive science has developed so as to help solve problems about mind, brain, and personality. It starts from „setting the scene" to „what next" and includes machine simulation, interdisciplinary beginning of

cognitive science, computational psychology, contributions of linguistics, connectionism, developments in neuroscience and philosophical aspect of mind. Chipman (2010) reviewed 30 years of progress in U.S. cognitive science research related to education and training. It was found that cognitive science has made significant progress in important areas of education like reading comprehension, mathematics learning and physics education. The cognitive science research approach has yielded instructional methods, sometimes embodied in artificially intelligent tutoring systems, sometimes in more traditional human-implemented teaching, that have been shown to produce significant improvements in student achievement. Education proved to be an important focus of and motivator for research in cognitive science. Srinivasan (2011) has placed Darmouth Symposium of 1956 as the official beginning of cognitive science in the paper "Cognitive science: Emerging perspectives and approaches". According to him, advances in key interfacing disciplines especially computer science, psychology, neuroscience and linguistics enabled the development of Cognitive Science as a discipline of its own studying the mind. Cognitive science is considered as a strong interdisciplinary effort to understand mind. The paper discusses the major approaches to studying the mind including the information processing approach, cognitive modeling, cognitive neuroscience, embodied and situated cognition as well as the emerging trends of increasing interdisciplinarity and pluralism in cognitive science.

Thus, it is apparent that though the „discipline cognitive science" is a product of last century only, its subject matter has developed gradually through different efforts in a wide area to understand the mind. Its origin may be rooted to as ancient times as that of the ancient Greek philosophers and its actual birth may be regarded to be as recent as the 1950s.

Concept of Cognitive Science

The emergence of the new field called "cognitive science" is one of the most significant scientific developments in recent years. It aims at studying cognition by pooling the resources of a number of disciplines, including cognitive psychology, artificial intelligence, linguistics, philosophy, neuroscience and cognitive anthropology. Cognitive Science is the study of the processes by which the humans and other animals come to know properties of their external environment and convert

that knowledge into action as well as relay that knowledge to others by means of communication. Broadly, it can be defined as the scientific study of minds and brains—natural or artificial, human or animal. Practically, it is delimited to the areas in which one can reasonably attempt at attaining real understanding. The researches in cognitive science have the prospects of serving several important areas—mental health, social engineering, education, computer technology, etc. Its growing and widespread applications has made cognitive science one of the four pillars of the 21st century, the other three being Nano, Bio and Information Technology. But cognitive science is the least represented out of these four pillars, particularly in the Indian scientific scenario.

Cognitive science as a field of study mainly aims at an integrated and concerned effort towards developing a complete theory of intelligent systems. It aims at—

(a) Developing a theory of intelligent systems.
(b) Drawing the architecture of cognition.
(c) Understanding how cognition enables an organism to interact with and adapt to its environment.

Intelligent systems have been described by different research approaches. Allen Newell and Herbert Simon"s work on the physical symbol system hypothesis supports much current work in cognitive science. They hypothesized that a necessary and sufficient condition of intelligence is the system"s ability to manipulate symbols. On the other hand, connectionist researchers focus on the perceptual and pattern recognition aspects of intelligence. Another aim is to draw the architecture of cognition, which means the structure of cognitive systems. And the last one is to understand how and how much cognition influences our behavior in relation to the environment.

Branches of Cognitive Science

Cognitive science, as an interdisciplinary study of mind and intelligence, encompasses a large network of key disciplines. These are philosophy, psychology, artificial intelligence, linguistics, anthropology, sociology, education, neuroscience, etc. These disciplines, which contribute towards understanding mind from different points of

view constitutes the branches of cognitive science. A brief description of the main branches of cognitive science has been attempted here.

Philosophy: In ancient times, philosophy referred to higher learning or development of knowledge. As such, philosophy is still considered to be the highest and oldest knowledge of the world. The scope of philosophy is very wide and comprehensive. It forms the foundation of almost every discipline. It endeavors to understand everything that comes within the realm of human experiences. It attempts to give a comprehensive view of nature and a universal explanation of the nature of things. The main branches of philosophy include—Metaphysics, Epistemology, Ethics, Logic, Aesthetics, Philosophy of mind, Philosophy of education, Philosophy of language, Philosophy of religion and Philosophy of science.

The epistemological branch of philosophy investigates the structure and growth of human knowledge by locating it in human minds and societies and is therefore, more closely associated with cognitive science. The agenda of cognitive science is set by the two and a half millennia old tradition of Western philosophy as well as the ancient tradition of Indian logic (Gardner, 1985). In recent years, „philosophy of mind" has been intimately associated with the field of cognitive science in several ways. One is that the results of cognitive science researches have potential applications to traditional philosophical problems in epistemology, metaphysics and ethics. Second, cognitive science can serve as an object of philosophical critique, particularly concerning the central assumption that thinking is representational and computational. More constructively, cognitive science can be taken as an object of investigation in the philosophy of science, generating reflections on the methodology and presuppositions of enterprise. Another role of cognitive science is putting new ideas and concepts in perspective, and linking them with abandoned or distorted ideas and concepts from the past.

On the other hand, philosophy plays a dual role in cognitive science. First, it provides cognitive science with both a world-view as well as ways to go beyond it in order to overcome the puzzles which arise from this world-view. In this role, philosophy functions as philosophy of science, in its proactive form. Philosophy also plays an important role in defining the basic analytic categories pertaining to thought, knowledge, perception, emotion and others.

It is important to note that the significance of philosophy is not lessened even by the two centuries of scientific psychology. Rather, its relevance has grown with the growth of various branches and programs of cognitive science. Here philosophy functions as philosophy of mind, in a broader sense. It also includes philosophy of psychology, philosophy of language, epistemology, ontology and phenomenology. Apart from contribution to these specific issues, philosophy also helps in global issues that relate the various sub-disciplines of cognitive science. It is traditionally concerned with the general problems on both a meta-scientific and commonsense (everyday) level. Another important prospect of philosophy is that it can help in constructing as well as evaluating the global theories that are necessary for further integration of the field of cognitive science.

Psychology: Psychology is defined as the study of human behavior, which was earlier considered to be the study of mind. But recently, it has confined itself to study of behavior. It adopts various approaches to study behavior. The field of psychology grew with the structuralist, functionalist, behaviorist and cognitivist views of behavior subsequently. The behaviorists dominated the field for a long period. But the later part of the twentieth century saw „cognitive revolution" which was dominated by the idea that cognitive processes can be scientifically studied. The final decades of the 20th century saw the decline of behaviorism and the rise of cognitive science, an interdisciplinary approach to study cognition. In 1957, Noam Chomsky challenged radical behaviorism by reviewing Skinner"s book „Verbal Behavior". He argued that people could produce an infinite variety of sentences unique in structure and meaning and that these could not possibly be generated solely through experience of natural language. As an alternative, he concluded that there must be internal mental structures. Similarly, work done by Albert Bandura showed that children could learn by social observation, without any change in overt behavior. This must be accounted for by internal representations. The rise of computer technology also promoted the metaphor of mental function as information processing. This combined with a scientific approach to study the mind, as well as a belief in internal mental states, led to the rise of cognitivism as the dominant model of mind and study of behavior in psychology.

The theoretical focus of traditional cognitive science is the computer simulation of the mind. It asserts that animal and human psychology occurs through computational

processes in organisms involving physical symbol systems. Psychological processes are realized in animals and humans by innate symbol systems in which the programs of the mind are initially given. These systems are subsequently modified through experience. This conception offers a theory of how cognition takes place in the organism—through the interaction of symbols that are processed by internal operations. Psychological experiments that approach mental operations from diverse directions are therefore crucial for cognitive science to be scientific. Major branches of psychology are developmental psychology, clinical psychology, educational psychology, experimental psychology, cognitive psychology, industrial psychology and social psychology. The branch of cognitive psychology is dedicated to the study of cognition and mostly contributes in the field of cognitive science.

Anthropology: Anthropology is the discipline that studies races, cultures, languages, and the evolution of the human species (Baker, 2007). It has origins in the natural sciences, the humanities and the social sciences. The term „anthropology" is derived from the Greek terms „anthropos" meaning „man" and „logia" meaning study. Its basic concerns are: „What defines Homo Sapiens?", „Who are the ancestors of modern Homo Sapiens?", „What are human"s physical traits?", „How do humans behave?", „Why are there variations and differences among different groups of humans?", „How has the evolutionary past of Homo sapiens influenced its social organization and culture?" and so forth. The field of anthropology covers a vast scope which includes the human body, the human evolution, biology and genetics. Modern anthropology has been divided into four branches—Cultural anthropology, Linguistic anthropology, Biological/Physical anthropology and Archeology. By the 1950s, the subfield of cognitive anthropology emerged out of a blend of linguistic and socio-cultural anthropology (Bender, Hutchins & Medin, 2010). In parallel with the cognitive revolution, cognitive anthropology blossomed in the 1960s and 1970s. It explored the organization of knowledge in a variety of domains in different societies. The definition of culture depends on the interest in knowledge and representation in other areas of cognitive science. Cognitive anthropology studies the relationship between culture and mind. It primarily studies knowledge and thinking in natural settings. Its main contribution has been to show that there are important cultural differences in perception, memory, and inference (Nuckolls, 1999). A collaboration between cognitive science and anthropology is productive due to anthropology"s interest in

cultural knowledge and meaning. It has been established after a series of experimental observations that culture affects both the thoughts and thought processes of the people. These observations include researches which show that language affects thought and the cognitive consequences of collectivism versus individualism. The cultural differences range from basic perceptual processing to categorization, reasoning, and attribution processes. These two kinds of observation build a bridge between anthropology and cognitive science. In the 1990s, some cognitive anthropologists took their inspiration from the fields of cognitive science and evolutionary psychology. They also aimed at combining the results of ethnographic studies with the findings and method of the sciences.

Linguistics: Linguistics is a field of study which is dedicated to understand, describe and explain the human faculty of language. It is the scientific study of human language. It can be broadly divided into three categories—the study of language form, of language meaning, and of language in context. The study of language structure or grammar focuses on the system of rules followed by the speakers of a language. The study of language meaning is concerned with how languages employ logical structures and real world references to convey process and assign meaning. Language in its broader context includes evolutionary linguistics, historical linguistics, sociolinguistics, psycholinguistics, neuro-linguistics, language acquisition, and discourse analysis. The major branches of linguistics may be considered as—Cognitive linguistics, Comparative linguistics, Computational linguistics, Descriptive linguistics, Generative linguistics, Historical linguistics, Language acquisition, Psycholinguistics and Sociolinguistics.

The evolution of spoken human language requires the development of two things—vocal tract and cognitive abilities. The first is used for speech production and the cognitive abilities are required to produce linguistic utterances. One of the significant abilities required for development of language is that of high level reference. It means the ability to refer to things or states of being that are not in the immediate realm of the speaker. There is a consensus that mind is necessary for language development and use. Therefore, the development of a full theory of mind in humans was necessary to understand language development in humans. Noam Chomsky (1957) argued that humans are born with a universal grammar hardwired into their brains. This universal grammar consists of a wide range of grammatical models that include all the

grammatical systems of the world‟s languages. Among the various branches of linguistics, cognitive linguistics in particular, attempts at understanding language creation, learning, and usage in reference to human cognition.

Artificial Intelligence: Artificial intelligence is a very important branch of cognitive science. It is originally a branch of computer science which studies and aims at producing intelligence of machines. It is defined as the study and design of intelligent agents, where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. The basic claim of the field was that the intelligence of humans can be precisely described and simulated by a machine. The branches of AI are—Representation and Logical AI, Constraint satisfaction, Bayesian networks, Machine learning, Neural networks, Planning, Knowledge engineering and Search.

Artificial intelligence and cognitive science are two distinct disciplines, with overlapping methodologies, but different goals. The central idea of AI is computational modeling of intelligent behavior. This is the main contribution of AI to cognitive science. Both artificial intelligence and cognitive science come within a framework that assumes that cognitive processes can be modeled in terms of manipulations of encoded symbols. Moreover, the recent developments of connectionism and parallel distributed processing share the basic assumption concerning the encoding nature of representation. However, the issue of manipulation is controversial. In all these approaches, representation is construed as a form of encoding correspondence.

Neuroscience: Neuroscience is the scientific study of brain and the nervous system. It helps to understand how we perceive and interact with the outside world. It studies the physical basis of our behavior. It is an interdisciplinary science that collaborates with other fields such as chemistry, computer science, engineering, mathematics, medicine, philosophy, physics and psychology.

Studies of brain have become more sophisticated after the invention of the microscope. This led to the development of the neuron doctrine—the hypothesis that the functional unit of the brain is neuron. The scientific study of the nervous system increased significantly during the second half of the 20^{th} century. It has become possible to understand the complex processes occurring inside a single neuron, and in

a network that eventually produces the intellectual behavior, cognition, emotion and physiological responses. Neurons form functional circuits, each responsible for specific tasks to the behaviors at the organism level. Thus, neuroscience can be studied at many different levels ranging from molecular level to cellular level. The major branches of neuroscience are—Molecular neuroscience, Cellular neuroscience, Behavioral neuroscience, Cognitive neuroscience, Computational neuroscience, Systems neuroscience and Developmental neuroscience.

Cognitive science is indebted to the field of neuroscience in general and, cognitive neuroscience in particular. Cognitive neuroscience addresses how mental functions are supported by the brain. The imaging studies in neuroscience have led to some generalizations about mental processes and about the human brain that supports them. These may be summarized under the headings of localization, interaction, control, and plasticity. High density electrical or magnetic recordings from the scalp and fMRI have made it possible to determine the time course of the activations and learn about the direction of information flow.

Neuroscience also attempts to understand the control signals that prioritize a particular way of doing a task. The networks underlying simple reflex activity becomes more flexible through experience. The activation of many networks is common to all people. It implies that it has genetic origins (Posner & Rao, 2009). But the working of these networks differs among individuals, which influences their performance. The individual differences among people are the results of interaction between gene and the environment.

Thus, the field of cognitive science crucially relies on an integration of the results produced by its core disciplines. This integration is very significant for the research in the separate disciplines to have an impact on cognitive research in general and also for the implementation of cognitive science in various social aspects. It is true that the assimilation of knowledge from different fields is an important characteristic feature of cognitive science. But additional original work is equally important. In an interdisciplinary area like cognitive science, it is necessary to integrate diverging (apparently) data and results of the contributing disciplines. For this, new concepts should be developed that can be used within different disciplines and increase the level of understanding between the different areas. It is also necessary to develop

general theories that bring together ideas from the various areas, synthesize them in a constructive way, and make it comprehensible to all parts involved. This synthesis may be done by philosophers who are trained in the philosophy of science and epistemology as they have a skill for critically assessing theories and methodologies. Thus the branches of cognitive science are intimately interrelated to each other. They contribute to the field of cognitive science as well as have the prospects of using the results of researches in cognitive science.

Components of Cognitive Science

The field of cognitive science is a vast area and includes a large number of psychological aspects related to cognition. Such aspects constitute the components of cognitive science. It includes attention, perception, memory, imagery, language and psycholinguistics, consciousness, knowledge representation, thinking, reasoning, creativity, problem solving, decision-making and emotion. Attention is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Perception is the process by which an organism attains awareness or understanding of its environment by organizing and interpreting sensory information. Memory can be defined as the mental storage of information and the processes involved in the acquisition, retention and retrieval of that information. A mental imagery is an internal representation that produces the experiences of perception in the absence of the appropriate sensory input. Language is a large collection of arbitrary symbols that have significance for a language using community, and that follow certain rules of combination. A central goal of cognitive science is to understand how human beings comprehend, produce and acquire natural languages. The term „consciousness" covers a wide range of cognitive functions, including voluntary actions, decision making, attention, awareness and self-monitoring. It is the normal mental condition of the waking state of humans, characterized by the experience of perceptions, thoughts, feelings, awareness of the external world, and often in humans, self-awareness. Knowledge representation is a central concept in cognitive science. Knowledge is described as representations of facts and concepts organized for future use. Thinking is a cognitive activity. It involves mental exploration of objects, activities and experiences instead of motor exploration. Reasoning is a complex mental process that needs a well organized brain. Reason is a means by which thinking comes from one idea to a related idea. More specifically, it

is the way rational beings propose and consider explanations concerning cause and effect, true and false, and what is good or bad. Reasoning may be inductive or deductive. cognitive science have attempted to study and explain how people reason, e.g. which cognitive and neural process are engaged in reasoning and how cultural factors affect the inferences that people draw. Creativity is the ability to improve, whereby through improvement value is added. Theories of creativity have focused on a variety of aspects. The most dominant are usually identified as the four Ps—process, product, person and place. Problem solving is an extremely complex activity that involves intellectual skills, knowledge and cognitive strategies and meta-strategies that modify attention, perception, the input and the storage of information, and the retrieval of knowledge form memory. Decision-making involves choosing among various options. It involves some problem-solving, since individuals try to make the best possible choice from a range of options. The focus in decision-making is on the factors influencing preference. Plato regarded in emotion to be one of the basic parts of the human mind along with reasoning and desiring. Emotions are related to cognition in at least three ways—as stimulants of cognition, emotions are cognitive in the sense that they involve propositional attitudes, the most literal interpretation of cognitivism about emotions would be committed to ascribing emotions a „mind-to-world direction of fit". All these components constitute the components of cognitive science as they are the elements which are studied in the field of cognitive science.

Cognitive Science as a Field of Study

Mind is the most complex entity in the whole universe. It is complex in the sense that it is not easy to study mind as it cannot be observed, measured or manipulated. Disciplines like science and philosophy have been answering various questions that arise in the life of human being. Science helps in our understanding of the external observable world. And philosophy helps in finding out the answers to the questions related to our life. Nevertheless, human mind has always remained dubious and mysterious, both to science and philosophy and to human beings in general. There were still many unanswered questions about the human mind.

In the past half century, mind has been the subject-matter of research, more than in all the time that came before that. This has also resulted in an increase in the number of disciplines that study mind. With the increase in these disciplines, new technologies

and methodologies for studying the mind have also been introduced. But the complexity of the mind has led the experts of these disciplines to attempt at a coordinated effort to understand it. This coordinated effort of the experts of various disciplines to understand the brain has emerged as the field of Cognitive Science. As science is famous for its acquaintance only with the external world, cognitive science as a field of study has distinguished itself from other sciences in that its full attention is on the discovery of our mental world or "inner space".

Cognitive science can be roughly summed up as the scientific interdisciplinary study of mind. It results from the efforts of researchers working in a wide array of fields—philosophy, psychology, linguistics, artificial intelligence, anthropology and neuroscience. Each field has its own unique set of tools and perspectives. Its primary methodology is the scientific method, although many other methodologies also contribute. Different methodologies are brought to bear on a common problem: the nature of cognition. The magnitude of complexity of the mind necessitates an interdisciplinary effort to study and understand it. No single perspective is adequate. Only an intercommunication and cooperation among the practitioners of these disciplines can result in an adequate study of mind. Study of cognition includes mental states and processes such as attention, perception, memory, imagery, language and psycholinguistics, consciousness, knowledge representation, thinking, reasoning, creativity, problem solving, decision-making and emotion. These constitute the components of cognitive science.

Cognitive science does not merely means the sum of all the contributing disciplines but their intersection or converging work on specific problems. So, cognitive science is not a unified field of study like each of the disciplines themselves, but a collaborative effort among researchers working in the various fields. The bond that holds the intersecting disciplines of cognitive science together is the topic of mind or their common goal to understand the mind and another is the use of scientific methods to study the mind.

To understand the field of cognitive science, it is necessary to know its theoretical perspective on the mind. This perspective centers on the idea of computation, which is also known as information processing. Cognitive scientists view the mind as an information processor. Information processor must both represent and transform

information. According to this perspective, a mind must incorporate some form of mental representation and processes that act on and manipulate that information.

Cognitive science tends to focus on a particular level analysis. It tries to understand minds as though they were computer programs. Cognitive scientists want to understand how information is processed in minds at a very detailed level. They want to understand cognition at a level of detail such that one could make a computer program that would process information in the same way. Cognitive science looks for explanations not like traditional computer programs, but explanations that are encoded at the computer-program level of detail. Most cognitive science explanations regard cognition as a program that is running on the networks of neurons. All these imply that cognitive scientists view the human minds as software running on neural hardware. The next level in which cognitive science has interest is the neural level. For explaining cognition, cognitive scientists are finding ways to link up the neural level to the information processing level.

Concept of Pedagogy

There is always a challenge to situate our knowledge in our living context. In the field of education, the living context is the classroom. So, the knowledge is to be situated in the classroom. Though the purpose of education has been broad as well as contextual, there are some universal motives with which the process of education goes on, for instance, the welfare of the learners. The process of education involves two fundamental functions—teaching and learning. The relation between teaching and learning may be stated as—teaching is the act of facilitating learning. However, sometimes learning may take place without teaching. In the field of education, cognitive issues are one of the vital issues. The cognitive issues in education include the way the minds of beings meet each other. The teacher‟s cognitive issue is to reach the student‟s minds and the students‟ cognitive issue is trying to get what is coming from the teacher‟s mind.

Pedagogy is the science of teaching. It is complex and difficult to define what constitutes pedagogy. Even the definitions of pedagogy appear to be somewhat obscure. Watkins and Mortimer (1999) define it as „any conscious activity by one person designed to enhance the learning of another‟. Alexander (2003) suggests that pedagogy requires discourse: Pedagogy is the act of teaching together with its

attendant discourse. It is what one needs to know, and the skills one needs to command in order to make and justify the many different kinds of decisions of which teaching is constituted. Leach and Moon (1999) described a *Pedagogical Setting* as „the practice that a teacher, together with a particular group of learners creates, enacts and experiences". Their definition suggests that pedagogy is a joint activity in which the learner has an active role. This offers a different perspective from previous definitions offered and draws in the social interaction between teachers and learners. Pedagogy involves the act of teaching and the rationale that supports the actions that teachers take. It is what a teacher needs to know and various skills that a teacher needs to use in order to make effective teaching decisions. It is what teachers ought to do to fully facilitate and support learning. The responsibility of the education process is to ensure that the children exploit their potentials to fullest. This can be done if proper learning takes place, which in turn is facilitated by teaching. So, the demand is to make pedagogy strong and well-developed.

Pedagogy is the study of the education of the child. The Soviet psychologist and educational reformer, Pavel Petrovich Blonskii regarded education as a deliberate, organized, and prolonged effort which influences the development of an individual. Pedagogy is establishing clearly and precisely how this effort may be organized, what different forms it may take, what techniques it may utilize, and what direction it should assume. For this, it is necessary to understand the laws that govern the development of the individual. Alexander (2004) argues that pedagogy is the act of teaching together with its attendant discourse. It constitutes the knowledge and skills necessary for making and justifying decisions in teaching situation. According to him, the teacher requires knowledge in three main domains: domains that enable teaching (whom, what and how of teaching); domains that formalize and legitimate teaching (requirements and expectations of the institution and local and national authorities); and domains that locate teaching (culture, how an individual relates to others and develops as a person, and how to understand the current and future state of education).

Pedagogy may be considered as both natural and normative science. On the one hand, it is a sub-field of the biological (i.e. natural) sciences since it has responsibility of developing the child. On the other hand, it deals with philosophical or normative sciences since every form of education sets for itself particular ideals, goals, or norms.

A pedagogy can be (1) *general*, as in the strategies, techniques, and approaches that teachers use to facilitate learning in general; (2) *specific to a domain*, such as the application of specific strategies, techniques, and approaches belonging to a domain to the instruction of that specific domain; or (3) *specific to a certain approach to teaching* that may or may not be domain specific, such as work-based pedagogy, problem- based pedagogy, or even constructivist pedagogy.

Pedagogy also includes the ways in which teachers interact with students. It implies issues like how they question and respond to questions, motivate students, use their ideas and respond to their diverse backgrounds and interests. It includes creating the social and intellectual environment and deciding on the types of learning to be engaged. It also includes the decisions about framing the content around a series of tasks or as key ideas and skills that are revisited and built on. Teachers also need to think about how they link and sequence activities and how and what they assess. All these decision-making by the teacher constitute pedagogy.

Relationship between Cognitive Science and Pedagogy

A strong relationship is evident between cognitive science and pedagogy. The applications of cognitive science in the educational process are straightforward. The main goal of the education process is to improve learning and performance of the students, which can be done through effective pedagogical intervention. A thorough understanding of the learning processes is vital for the deployment of adequate curricula and teaching methods. Teaching does not constitute only the content and the method of presenting the content but it should also take into account the information processing in the learner, accessing a learner‟s cognitive structure (prior knowledge) to determine whether it is adequate to process the new information, problems in processing the information and ways of overcoming these problems. A better understanding of the neural underpinnings of learning mechanisms and cognitive functions involved in the educational process (memory, attention, motivation, perception, metacognition) has obvious implications for effective pedagogy. The most significant implication is the designing of effective learning tools and educational paradigms by using the principles and researches on cognitive science. It is only when the complexity of teaching reaches parity with the complexity of learning that there will be significant improvement in levels of classroom learning and performance

(Letteri, 1991). Teaching, to a large part, is based on the assumptions about the mind of the learner. Therefore, it is important for the teacher to determine what children think they are doing and what their reasons are for doing it, apart from knowing what they do. Teaching begins with a teacher‟s understanding of what is to be learned and how it is to be taught. Though the teacher is responsible for designing learning opportunities for the learners, learning itself ultimately remains the responsibility of the students. Thus, teaching is inevitably based on the notions about the nature of the learner‟s mind. When the teacher attempts at teaching something to the learners, it is based on the assumption that the learners are either ignorant of something or what they believe is false. Gardner (1991) puts it in his "The Unschooled Mind" as "We must place ourselves inside the heads of our students and try to understand as far as possible the sources and strengths of their conceptions." Modern pedagogy is emphasizing more and more on the cognitive paradigm. It is developing a strong view that the child should be aware of her own thought processes. Therefore, it is crucial for both the pedagogical theorist and the teacher to help the child to become more meta-cognitive. It implies that the improvements in pedagogy require the understanding of the learners‟ mind. Cognitive science is the field which can best help at a comprehensive understanding of the human mind.

Cognitive science researches are concerned with the structure and representation of knowledge in our minds. Pedagogy is concerned with sharing of this knowledge among many brains. The innovative models and theories that have been proposed to facilitate advancement in the field of pedagogy tend to focus on cognitive factors.

Bruner (1999) mentioned about four models of learners‟ minds. These are—

(a) Imitative Learners—When an adult demonstrates or models a successful or skilled action to a child, that demonstration is implicitly based on the adult‟s belief that—

- The child does not know how to do x
- The child can learn how to do x by being shown
- The child wants to do x
- That the child may, in fact, be trying to do x

To learn by imitation, the child must recognize the goals pursued by the adult, the means used to achieve those goals, and the fact that the demonstrated

action will successfully get the child to the goal. However, learning by a combination of practice and conceptual explanation is more effective for gaining flexible skills than just learning how to perform skillfully.

(b) Learning from Didactic Exposure—Didactic teaching is usually based on the notion that the pupils should be presented with facts, principles and rules of action which are to be learned, remembered, and then applied. It assumes the child to be ignorant of certain facts, rules or principles that can be conveyed by telling. In this teaching situation, abilities are conceived as the ability to acquire new knowledge by the aid of certain „mental abilities", verbal, spatial, numerical, interpersonal, or whatever. This model presumes that the learner"s mind as tabula rasa. The mind accumulates knowledge cumulatively, which implies the importance of prior knowledge. It considers the child"s mind as passive, a receptacle waiting to be filled. Active interpretation or analysis does not enter the picture.

(c) Children as Thinkers—According to this model, the teacher is concerned with understanding what the child thinks and how that belief came into being. Pedagogy is to help the child understand better and holistically. Understanding is fostered through discussion and collaboration. The learners are encouraged to express their own views to achieve some meetings of minds with others who may have other views. Such pedagogy of mutuality presumes that both child and adult have their own points of view, i.e. the concept of individuality. Each is encouraged to recognize the others, though they may not agree. The child is assumed to be able to reason, to make sense, both on her own and through discourse with others. This model of education is mutualist and dialectical, more concerned with interpretation and understanding than with the achievement of factual knowledge or skilled performance. Recent researches on inter-subjectivity (how children develop their ability to „read other minds"), theories of mind, meta-cognition and collaborative learning have enriched this perspective on teaching and learning.

(d) Children as Knowledgeable—The fourth perspective holds that teaching should help children grasp the distinction between personal knowledge, on the one side, and what is taken to be known by the culture, on the other. We come

> to view personal against the background of what has come to be shared with the historical past. Those presently engaged in the pursuit of knowledge become sharers of conjectures with those long dead. Thus, there is something special about „talking" to authors, now dead but still alive in their ancient texts—so long as the objective of the encounter is not worship but discourse and interpretation, „going meta" on thoughts about the past.

It is seen that each model emphasizes different educational goals. These models are conceptions of mind that determine how teaching is carried out. In the first model, practice and conceptual explanation have been given importance. The second model considers the learner"s mind to be passive. So, it gives importance on putting new knowledge in their minds on the basis of previous knowledge. The third model gives importance to individual difference and therefore, discourse and dialogue are encouraged. The fourth model emphasizes on meta-cognition of the learner.

Rationale of the Study

Cognitive science is an emerging science. And being a vast and extensive area of study, including a large number of disciplines within its scope, it has made itself able to serve almost every field of human life. The field of education is not an exception. Rather at present, cognitive science paradigm in education is dominating the field, and it opens up a number of scopes for research. It is generating a lot of research in the area of students" understanding. But its translation into actual classroom practice has been limited. It was found that there are very limited studies on cognitive science. The available studies are mostly relevant to neuroscience or conducted from the perspective of neuroscience. Some research articles have established the implications of cognitive science on different aspects of education like curriculum, instructional methods for specific subjects, etc. The review of the studies conducted on the components of cognitive science drawing implications on education reveals that there are very limited studies on these. Studies on learning (12 studies) were conducted on knowledge construction (King, 1994), teaching higher order thinking skills (Ivie, 1998), application of cognitive science principles in organization (Peneul, 1999), changes in learning processes as a result of instructions on learning processes (Clump, 2005), use of Socratic Method for higher level learning (Whiteley, 2006), facilitating conceptual and procedural knowledge (Rittle-Johnson & Star, 2007), role of

manipulative and meta-cognition on learning (Belenky and Nokes, 2009), integrative learning (Brown Leonard, 2008), benefits of collaborative learning (Gadgil & Nokes-Malach, 2011) and learning from cognitive informatics perspective (Yao, 2004). Studies conducted on problem solving (8 studies) include studies on problem-solving strategies (Saxena, 1980), effect of belief systems, interactions with environments and skills of decision making on problem solving (Schoenfeld, 1983), importance of memory, reasoning and content-based thinking on problem solving (Ross, 2007), pedagogical problem-solving (Simone, 2008), use of diagrams, story and equation representations in problem solving (Booth & Koedinger, 2011), collaborative problem solving (Mead, Nokes & Morrow, 2012), lessening cognitive load on problem solving task and role of technology in it (Limjap, 2002). Studies on creativity (11 studies) include using creative method of teaching language (Nandanpawar, 1986), approaches to teach children to think creatively (Torrance, 1987), effects of creative thinking programmes (Amin, 1988), effect of various factors on creativity (Sharma, 1982; Trimurthy, 1987), teaching methods and instructional approaches, styles and methodologies that promotes creative thinking (Hamza & Griffith, 2006), teachability of creativity and mutual involvement of teachers and student in it (McWilliam, 2007), multidimensional activity based integrated approach to develop creative abilities (Basantia & Panda, 2010), strategies and supportive environment for fostering creativity (Lin, 2011). The studies found on intelligence (5 studies) include studies on classroom implications derived from various theories of intelligence (Fogarty, 1998), adopting a middle ground between the two extremes of general intelligence and multiple intelligence (Sternberg, 1999), relevance of brain research on intelligence to education (Haier & Jung, 2008), inter-relationship between Gardner‟s eight intelligences (Watve, 2010) and meta-epistemology of knowing-how (Tsai, 2011). The studies on attention (7 studies) are related to application of cognitive notion of attention on Second Language Acquisition (Tomlin & Villa, 1994), workings of cognitive model of attention for the development of literary knowledge (Hanauer, 1999), enhancing attention by using animating multimedia content (Feil, 2009), attentional blink (Srivastava, 2009), attention and information access (Baijal, 2010), enhancing attention by manipulating spatial format of instructions (Jang, Schunn & Nokes, 2011) and association of attentional dimensions with cognitive performance (Aran-Fillippetti & Krumm, 2013). The studies on implications of cognitive science on education as a whole (16 studies) include studies on application of cognitive

science principles in education (Glaser, 1988; Leong, 1993; Cobb, 1997; Kala & Ramadas, 2001; Halpern, 2002; Siegler, 2003; Klahr & Li, 2005; Metcalfe & Kornell, 2007; Schunn, 2009; Tytler & Prain, 2010), implications of brain research on education (Kruse, 1998; Krane & Richardson, 1999), relation between cognitive neuroscience and education (Ansari and Coch, 2006), use of cognitive and metacognitive strategies in science (Aykol, Sungur & Tekkaya, 2010), impacts of metacognitive skills on test performance (Roebers, Schmid & Roderer, 2010). (The references of this paragraph are given in the fourth chapter of the thesis).

From all these studies, it can be seen that there is a strong relationship between cognitive science and pedagogy. The researches in cognitive science may serve very useful in improving many aspects of pedagogy. But there is the need of in-depth studies on it. The store of research works on cognitive science lacks theoretical and philosophical study. It was found that no direct study has been conducted on drawing pedagogical implications of cognitive science, particularly in India which persuaded the researcher to raise the following research questions, such as—

1. How did the field of cognitive science emerged?
2. What constitutes the field of cognitive science?
3. Whether cognitive science has any implications in education?
4. How the components of cognitive science are relevant to education?
5. What are the problems which arise while practicing these components in the teaching-learning process?
6. How can we make use of various components of cognitive science in teaching learning process?

Statement of the Problem

To find out the answer of the above issues, the present study entitled **"COGNITIVE SCIENCE AND ITS PEDAGOGICAL IMPLICATIONS"** was taken up with the following objectives.

Objectives

Following are the objectives of the study—

(1) To study the historical development of cognitive science as a field of study.

(2) To study cognitive science in Indian perspective.

(3) To study the various components of cognitive science.

(4) To study the uses of various components of cognitive science in the field of education.

(5) To study the problems in practicing these components in teaching-learning process.

(6) To suggest some guidelines for effective use of different components of cognitive science for pedagogical improvement in the field of education.

The historical development of cognitive science will be studied by reviewing various literature related to the subject. Indian philosophical and psychological literatures will be analyzed for tracing the concept of cognitive science in Indian perspective. The components of cognitive science used in the field of education will be studied by reviewing the curricula and syllabi of educational psychology in the post-graduate level. How various components of cognitive science are being used in the field of education process can be studied through analysis and meta-analysis of relevant research studies. While practicing these components in the field of pedagogy, the teacher may face various problems which will also be identified through analysis and meta-analysis of various research studies.

Operational Definitions

- **Cognitive science** - The field which studies cognition from an interdisciplinary perspective for its holistic and comprehensive view.
- **Pedagogy** - The science of teaching or the field which studies what the teacher ought to do in a teaching learning situation to make it more efficient.

Delimitations of the Study

The field of cognitive science is very vast. The field itself is composed of mainly six disciplines which makes it very extensive. It is not possible to study all the branches and components of cognitive science in a limited period of time. Therefore, keeping the time constraint and other constraints in mind, the researcher has taken only five components of cognitive science under study. These are learning, intelligence, creativity, attention and problem solving.