# CHAPTER 7

# MAJOR FINDINGS AND CONCLUSIONS

## Introduction

After analyzing and interpreting the data, the researcher has drawn out the major findings of the study. The findings are drawn from the analysis and the conclusions are arrived at on the basis of the interpretations of the major trends manifested in the analysis. The findings are presented on the basis of the objectives. After the findings and conclusions, the suggestions for further research are given. The major findings of the study after analysis and interpretation of the data are:

## Emergence of Cognitive Science

From the study it appears that the roots of cognitive science may be found in the ancient philosophical discussions, though it was formalized into a discipline much later. It was found that the historical development of cognitive science can be divided into two stages for the convenience of understanding—early history of cognitive science (developments in its contributing disciplines which may have effected in the emergence of cognitive science) and the formal conception of cognitive science.

The foundation of cognitive science may be laid upon the epistemological developments in the field of philosophy. On that base, developments in other disciplines—psychology, linguistics, anthropology, neuroscience and artificial intelligence—have built on to understand the mind.

The subject matter of cognitive science—„cognition" i.e. knowing—is the central point of epistemological discussions in philosophy. The rivalry between the methodologies of pure reason (rationalism) and sense experience (empiricism), as the means for gaining knowledge, and particularly the rationalist approach laid the foundation for cognitive science. In the field of psychology, the nature of the subject matter itself was a concern of controversy. After fixing its subject matter as „the study of behavior", the controversy started on the approach to study behavior. At first, the field was dominated by the behaviorists (only observable behavior is accountable), then Gestalt psychology emerged and at last cognitivism and constructivism found a strong hold on the discipline. Now the field of psychology is mostly dominated by the theories of constructivism and information processing. In the early part of the history of linguistics, the concern was more about phonetics, morphology and syntax. In the later part, grammar came to focus. The notion of the universal nature of grammar emerged in the 12th century Europe. The schools of linguistics that emerged are divided under two types—formal and functional—on the basis of whether they adopt an overall focus on form or on function. In modern linguistics, the idea was that a language can be viewed as a self-contained and structured system. The history of neuroscience has been shaped by three major debates: mind vs. brain debate (monism/dualism); localism vs. holism; and the nature of neural communication. Today localism dominates neuroscience. Cognitive science encompasses both localization and holism. However, extreme localism and holism is being replaced by „connectionism". This view contends that lower level or motor functions are strongly localized but higher level functions are the results of interconnections between the brain areas. The field of artificial intelligence has developed with the endeavours of developing intelligent machines. These endeavours include designing calculating machines, computers, cybernetics, robotics, computational devices and programming languages, information processing and knowledge representation.

Cognitive science got its formal conception in the 1950s in a conference of scholars of various disciplines. It developed with the contributions of various thinkers in different disciplines in the symposium held on information science at the MIT, Boston on 11th September, 1956. Disciplines like philosophy, psychology, computer science, neuroscience, linguistics and anthropology converged at the symposium. In 1960, the Centre for Cognitive Science was established at Harvard. The Sloan Foundation established a program in cognitive science in 1976 and conceived it as „an autonomous science of cognition". The publication of the journal "Cognitive Science" and the first conference of the Cognitive Science Society at the University of California, San Diego in 1977 are regarded as the formalization of the enterprise as a properly recognized scientific discipline. Thus, an interdisciplinary field of cognitive science emerged and was institutionalized.

## Cognitive Science in Indian Perspective

From the reflection of Indian philosophy, it appears that the concept of cognition is very much intrinsic to Indian philosophy and psychology. Both the orthodox and heterodox schools of thought have clear account of cognition and cognitive science. The Vedic philosophy has propagated the knower, the known, and the means of knowledge and also valid knowledge which is acquired through perception, inference and scriptural testimony. It also highlights inference, analogical reasoning, cognition, memory dispositions, etc. It also refers the doctrine of valid knowledge, especially the *buddhi* played an important role for the *pramanas* which is evident from the Yoga philosophy. *Anubhuti* also has a place in cognitive science. Comparison, pre-supposition and non-apprehension are also taken into consideration in Indian cognitive science. Sensory knowledge has a special reference in Indian philosophy. Along with it, the knowledge is considered as an intrinsic property of the individual in the heterodox philosophy. Therefore, none of the schools is contrary so far cognitive science is concerned. All the schools have emphasized the role of mind in cognition, i.e. acquiring valid knowledge. But the difference lies in the role played by the mind. For instance, while the Buddhist philosophy regards it as one of the sense organs, Yoga philosophy regards it to cause difference in perception of the external world.

### Components of Cognitive Science

It was found that any process in the life of human beings which involves the mind is a component of cognitive science. Because cognitive science attempts to understand the mind, and this endeavour is possible only through studying the processes related to the mind. Thus the psychological aspects related to cognition constitute the components of cognitive science. Further, man has tried to simulate the cognitive processes in machine with two aims in view—to understand every detail of mind or cognition as well as to attempt at construction of machines with cognitive abilities. This also comes under cognitive science. Thus, the components of cognitive science include cognitive processes like intelligence, memory, language development, creativity, attention, perception, mental imagery, knowledge representation, consciousness, motivation, learning, problem solving, emotions, action, thinking, pattern recognition, artificial intelligence, reasoning, decision making.

### Areas of Cognitive Science in Education

It was found that most of the components of cognitive science are very much relevant in the field of education as cognition is a core theme in the educational process. However, the researcher selected only five components of cognitive science for the present study which are used in the field of education.

**Learning:** As learning is a key concept in the field of education, knowledge about the processes of learning helps in devising better education systems. Therefore it is necessary to understand learning and the cognitive processes underlying learning. Teaching is concerned with the cognitive capabilities we want the learners to have, not what we want them to know. Further, it also helps in designing pedagogy for facilitating the cognitive processes underlying learning. Pedagogy should be designed based on these cognitive processes. The understanding of the concept of learning helps the teacher to understand his pupils. It gives him the confidence to deal with the students and the ability to control and manipulate the teaching methods and materials.

**Problem Solving:** Problem solving was found to occupy an important position in the teaching learning process. Its significance in education may be understood by the fact that the teaching attempts to improve students' ability of problem solving. It was found that the efforts made to improve students‟ problem solving abilities are inadequate. Therefore, it is a challenge for the teacher to understand better the cognitive processes underlying problem solving and to develop pedagogy to teach problem solving effectively. Cognitive science as a discipline aids education to understand the cognitive processes underlying problem solving and thus facilitate teaching of problem solving.

**Creativity:** The relevance of creativity in education is that education holds the responsibility to develop and foster creativity among learners. If education aims at generating productive human beings, it is necessary to understand and nurture their creative potential. Good education, proper care and provision of opportunities for creative expression inspire, stimulate and sharpen the creative mind, and it is in this sphere, that the teachers make a significant contribution. They are required to help the learners in nourishing and utilizing their creative abilities to the utmost. This can be achieved by acquainting the teachers with the real meaning of the creative process, the cognitive processes underlying creativity and the ways and means of developing and nurturing creativity.

**Intelligence:** Regarding intelligence, the education system has to cater to different levels and types of intelligence of the students and has to develop their intelligence accordingly. The teacher has to design his pedagogy with the aim of improving intelligence based on the cognitive processes underlying intelligence. The teacher can do this efficiently only if he understands the concept of intelligence and the underlying cognitive processes of intelligence. Cognitive science is the best way of understanding intelligence systems, both in human and in machine.

**Attention:** It was found that attention is an important component of education as it is closely related to the processes and products of learning. The teacher has to design his pedagogy on the basis of these mechanisms and processes. Good attention skill is very important for the students as they need to attend to instructions, focus on the details of the subject matter, and retain that attention until the task is complete. The pedagogy has to be designed keeping in mind that maintaining attention is a skill. It has to be trained and practiced. Teachers must understand the basic mechanisms and processes that regulate attention. This can be done with the help of cognitive science, as attention forms one of the much focused topics of cognitive science.

## Problems in practicing the components of cognitive science in the teaching-learning process.

After the study, it has been found that while practicing these components, the teachers have to face different kinds of problems. The researcher found the following problems regarding the use of components of cognitive science in pedagogical context.

### Learning

The problems regarding learning include misinterpretation about the concept and purpose of learning, inability to relate new knowledge with the existing ones, mismatch of pedagogy and the content to be delivered, presenting fragmented knowledge to the students less time for practicing for which the learners cannot internalize the concepts, inability to control all the components of the environment all the time to facilitate knowledge construction and designing the pedagogy keeping in mind both individual and social nature of learning.

**Problem Solving**

It was found that the teacher faces a number of problems while teaching problem-solving in the classroom. This includes students" haphazard approach towards problem solving, lack of background knowledge that is necessary to solve the problem, lack of knowledge of how to apply the background knowledge appropriately, less importance on describing and analyzing the problem, more reliance on knowledge than on reasoning. Even the teachers mostly resort to examples to teach problem solving, and thus ignoring the reasoning part of the problem solving process. Thus, it was found that more than the problem solving itself, the difficulty in understanding the process of problem solving creates difficulty for the teacher.

**Creativity**

In the context of creativity, rigidity of routine and definite time frame of classroom activities was found to stifle the creativity of the students. Some common misconceptions about creativity also hinder development of creativity in the classroom. Excess media consumption and standardized testing have also been found to hinder creativity. Another problem is to maintain a balance between the nature of the creative children (hyperactivity, high verbality, non-conformity, etc.) and the academic routine that has to be followed. Drawing a line between structured and unstructured environment to be provided in the classroom poses as a considerable dilemma.

**Intelligence**

The teacher faces various problems while dealing with intelligence in the classroom. The complexity of the concept of intelligence creates various problems for the teachers to deal with the intelligence of the students. The teacher faces difficulties of reliably measuring “unconventional” (e.g., creative and practical) abilities and differentiating them psychometrically from abilities measured by more conventional tests of intelligence and achievement. Another problem is intellectual relativism, wherein students' failures are explained away as being an example of a different kind of intelligence, not a lesser one. This leads to leaving the learner"s weak areas as they will not make any effort to make developments in these areas.

### Attention

It was found that directing the interest of the students or bringing the focus of their mind to the task at hand is a problem. The teacher"s task is to identify the natural interest (natural distractions) of the learners and direct their attention towards the task without forcing them. Deciding about the amount of exposure to hold the attention of the students is another problem. Presenting the learning materials to the learners so as to attract their natural attention is also a problem. Handling the split attention of the students is another issue to be addressed. Another problem faced by the teacher is to deal with the Attention Deficit Hyperactivity Disorder children. Providing attentional feedback at the appropriate time and appropriate way is also a problem.

## Guidelines for effective use of different components of cognitive science for pedagogical improvement in the field of education.

Keeping in view the problems faced by the teacher to use the components of cognitive science in the field of education, some guidelines have been suggested as implied from their cognitive theories. Though a comprehensive study has been attempted using meta-analysis, these guidelines are not exhaustive.

### Learning

It was found that the principles and theories of cognitive science help to make learning more effective. Important issues in learning involve goals of learning, presentation of the subject matter, method of delivering the content and the environment of learning. The cognitive theories of learning imply that learning should be purposeful and goal-oriented and the goals should be attractive for the learners. The subject matter should be presented in a structured pattern, sequentially, as a whole (at first), based on the past knowledge and with variety of examples and representations. The teacher should attempt at developing interest in the subject matter itself rather than giving external motivation. He should help in finding out the common elements in content, relationships among the information and in generalization. Pedagogy for learning should always adopt problem solving approach. Learning should be based on reasoning, intuitive and analytic thinking, imagination and creativity. Techniques like cognitive mapping, chunking, automaticity, dual processing, questioning, examples, analogies and mnemonic devices are very useful method of making learning effective. Learning becomes more effective with development of the metacognitive abilities of the learners. For teaching conceptual and procedural knowledge, the pedagogy should accommodate comparing and contrasting solutions by the learners. The cognitive informatics perspective is also useful for concept formation. Moreover, the learners should be given activities individually or in small groups. The environment should instigate spontaneous interaction with the environment. An environment of co-operation, collaboration and varied experiences with opportunities for adequate practice should be provided to the learners.

**Problem solving**

It appears that cognitive science focuses more on the internal representation of both the problem as well as the solution. Moreover, it emphasizes that while teaching problem solving, the solution process is more important than the solution itself. The pedagogy should ensure that the students are equipped with the kind of knowledge required to learn to deal with problems—making wise decisions, recovering from deadlocks, pursuing a systematic approach likely to lead to success. The pedagogy should focus explicitly on decision processes and teach these within the framework of a systematic strategy for solving problem. The most widespread approach to training in problem solving is to instruct the learner in various general principles that have emerged from theoretical analysis of the thinking process and from comparative observations of successful and unsuccessful problem solvers. The students should not be taught to find solutions to a particular problem or type of problem but they should be encouraged to generate solutions for different types of problems on the basis of solution processes of the problems encountered earlier. Proficiency in problem solving is best achieved in recognizing the essence of a given problem and the application of the proper problem solving heuristics.

Their metacognition should be guided and they should be given sufficient time to ponder over the problem. The teacher should always keep in mind that the problem solving process of the experts and the novices differ substantially.

**Creativity**

It was found that the problems in teaching creativity can be overcome by employing the principles of cognitive science in pedagogy. First of all, the pedagogy must be based on the belief that creativity can be taught. And accordingly, the pedagogic practice should be sensitive and imaginative which provides a gentle and catalytic influence. There should be great emphasis on teaching creativity in domain or subject-matter contexts and on helping students see the potential use of creativity in real life-situations. Developing creativity should be viewed as a long-range process leading to adult creative achievement and self-fulfillment. The teacher should feel secured to depart from traditional methods and conclusions and should be open to receive various non-conformities. The teacher should allow adequate freedom to the children in responding to a situation and avoid expecting fixed responses from the learners. The individuality of each learner should be respected to build up their confidence. The teacher should teach the students to develop a positive attitude towards every work and towards the failures which may come on the way. The teacher should expose the learners to variety of the curricular as well as co-curricular activities; so as to give ways to creative expressions. The learners should be engaged in creative problem solving. Multi-sensory experiences should be provided. Learners of different learning styles should be allowed to succeed. The pedagogy should be experimental and error-welcoming. Team teaching also helps in teaching creativity by exposing the learners to variedness. Other useful techniques are brainstorming and gaming techniques. The assessment and evaluation process should be more creativity-friendly, which includes self-assessment, peer-assessment and assignments. Moreover, there are various programs which have been developed to teach creativity.

**Intelligence**

The principles of cognitive science also imply that intelligence can be taught effectively by considering some points. Teaching for all types of intelligence is important. It is important to capitalize on the learning preferences of the students which are directly linked to their strongest abilities (intelligences). There should be diverse assessments of school achievement. Teaching should be organized to allow multimodal delivery in response to diversity in students‟ ability. Instead of labeling students‟ intelligences, several types of intelligences should be allowed to develop. Different pedagogical approaches should be used. There should be emotional safety and care for all learners. The teacher should provide rich learning environment in the classroom and provide challenges through experience of doing. Linguistic intelligence may be enhanced through books, journals, dialogue, stories and debate; logico-mathematical intelligence by chemistry sets, trips to the planetarium and science museums; spatial intelligence through paints, clay or play dough, videos, art museums and movies; bodily kinesthetic intelligence by role playing, sports and hands-on instruction; musical intelligence by singing, concerts and playing musical instruments; interpersonal intelligence by friendship, clubs, group games and mentors; intrapersonal intelligence by spending time alone, independent study and making choices; and naturalist intelligence through observing through binoculars and microscope, and interaction with plants and animals. Thus the pedagogy should involve varied experiences to cater to different types of intelligence.

**Attention**

The principles of cognitive science also help in designing pedagogy for improving attention of the learners. It was found that a very important thing for effective pedagogy is to overcome the reflexively instinctive nature of attention of the learners. The attention of the learners should be directed taking their natural interest as the starting point. The teacher should orient the subject matter according to the natural inclination of the child and from there he can gradually demand attention for the required tasks. The pedagogy is to be designed in such a way as to utilize the natural interests of children in motivating the children towards the task in hand. To develop attention as a skill, pedagogy should incorporate engagement of the learners in concentrative meditation training. Providing attentional feedback and rewards helps in dealing with the problem of attention in the classroom. Distributing instructions while holding task material format constant helps to overcome split attention effect.

The following implications are revealed in relation to the pedagogical problems in various areas of cognitive science. Five major areas of cognitive science have been taken into consideration in this study and twenty-seven major pedagogical problems have been identified which have already been discussed in the analysis chapter. However, the following significant points have emerged out from the study with regard to pedagogical problems and their implications under the purview of cognitive science—

1. **Learning:** Pedagogical problems arise in the area of learning if the concept of learning is not properly understood and the goals of learning are perplexed. These can be solved by providing instructions in learning processes both to the teachers and the learners. This, along with comparing and contrasting solution procedures, will also help in differentiating learning form knowledge accumulation. The problem of connecting new learning to previous learning can be solved by presenting the past and present knowledge in an integrated way. Adopting problem solving approach and giving more importance to the value of the content than to the content itself will help in solving the problem of mismatch between content and pedagogy. Another problem in the area of learning is fragmented learning for which insightful learning and presenting the subject matter based on Gestalt principle (whole to part) is important. More time for practice should be given to the learners for internalization and meaningful learning. Other problems related to learning are knowledge construction among the learners and maintaining both the social and individual nature of learning. This can be solved by using Socratic method among the students as well as with the teacher, by providing a resourceful classroom and facilitating collaborative learning in small groups.
2. **Problem Solving:** In the area of problem solving, haphazard way of solving a problem creates obstacles. It can be dealt with by considering the factors of

problem solving and promoting meaningful learning rather than rote learning. Lack of background knowledge and its proper application is another problem. This can be solved by using mental models to represent the structure, using intuition and logic to develop problem solving skills, providing guided metacognition, using variable problem context and facilitating analogy. To understand the problem properly, it is necessary to recognize the essence of the problem, give sufficient time to the learners to ponder over the problem and represent the problem appropriately. The problem of using only knowledge rather than reasoning can be solved by focusing on the process of problem solving rather than its product and using concrete thinking while solving the problems. Another problem is that the decision making process is given very less importance while teaching problem solving. There should be explicit focus on the decision making process in problem solving.

3. **Creativity:** The problems related to creativity are rigidity, excess media consumption, structured environment, maintaining balance between the nature of creative learners and others, and misconceptions about creativity. The pedagogical implications identified are providing an open and challenging environment to the learners, practicing creative problem solving, using techniques like brainstorming, thumbnail sketches, synectics and matrixes, making teaching experimental and error-welcoming, appreciating learner‟s individuality by building the self-confidence of the learners, adopting sensitive and imaginative pedagogic practices and believing that creativity can be developed.
4. **Intelligence:** The problems related to intelligence include creating an intelligence-friendly environment, evaluating intelligence and handling intellectual relativism. Providing a rich, challenging and emotionally safe learning environment will make the classroom intelligence friendly. Authentic and diverse methods of assessment should be used to evaluate intelligence. Intellectual relativism can be handled properly by teaching all types of intelligence, adopting multimodal delivery (techniques, tools and strategies of teaching) of content, considering individual differences and avoiding labeling of intelligence.
5. **Attention:** The pedagogical problems related to attention like managing numerous stimuli and Attention Deficit Hyperactivity Disorder can be solved by concentrative meditation training. It is difficult to identify and cater to different natural interests of the learners. It can be dealt with by intervening in their natural

interests, bringing them together, grouping them, preserving some, stimulating some and channelizing others. For handling the problem of split attention among the learners, distributing instructions while holding the task material format constant is suggested.

Thus it can be seen that to solve various pedagogical problems while practicing various components of cognitive science, it is important to understand and utilize the cognitive processes, cognitive mechanisms and cognitive structure of both the learners and the teachers.

**Postscript**

The present study was an attempt to acquaint with the newly emerged field of study—cognitive science—and draw its implications in the field of pedagogy. 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, be they real or artificial, human or animal. The field of cognitive science is the result of pooling the resources of a number of disciplines, including cognitive psychology, artificial intelligence, linguistics, philosophy, neuroscience and cognitive anthropology. To know a field, it is important to understand its evolution. It appears from the study that cognitive science has emerged as a field of study during 1950s. Although it had its trace during the ancient Greek philosophy in the west and in India, cognitive science had its origin in Indian philosophy and psychology which is very ancient. However, hardly any attempt has been made in the field of education (here, education as a discipline in a broader sense) to examine the implications of cognitive science in pedagogy neither through a theoretical meta-analysis nor a descriptive or experimental study. The findings of the present study reveal that cognitive science is a vast field of study and consists of a number of components. Most of the components are relevant in the field of education at any level of education—from primary to higher education. However, only five components of cognitive science used in the field of education have been taken under consideration in the present work—learning, creativity, intelligence, attention and problem solving. It was found that the pedagogical problems faced by the teachers in using these components in the classroom may be solved to some extent through implications drawn out from the cognitive theories of the components. From the study, it may be concluded that a rich environment in the classroom is a very significant aspect of effective pedagogy for all the five components; rich in material, emotional, social and cognitive sense. The environment should be encouraging, stimulating, sensitive and imaginative. However, for holding the attention of the learners, it is necessary to determine an appropriate amount of exposure or stimuli for the learners. Meditation training is also suggested for solving classroom problems related to attention. Next, it is important for the teachers as well for the learners to understand the concept of these components themselves. For instance, for effective learning, it is essential to understand the essence of „learning‟ or what actually constitute „learning‟. The pedagogy should be based on individuality of the learner. So, pedagogical activities should be given individually or in small groups. It should focus more on the process than on the product. The pedagogy should be reason-based rather than mere knowledge-based. Thus, by applying the principles and theories of cognitive science, the pedagogic practices may be made more effective.

## Suggestion for Further Research

The present study is concerned with the study of historical development of cognitive science, its components, the components used in the field of education, problems in practicing them and suggesting some guidelines. Cognitive science is a vast field and has enormous applications in different fields of study. Due to time and resource constraints, the researcher could not cover all the important aspects of the field. Some of the areas for further research may be:

1. The present research has carried out study only on five components of cognitive science. Researches may be conducted on other components in similar lines.
2. Apart from pedagogical implications, implications in other aspects of educational field may be studied.
3. Studies may be carried out with experimental methods to draw out the pedagogical implications.
4. Pedagogical problems and implications for a particular stage of education may be studied.