CHAPTER 4

REVIEW OF RELATED LITERATURE

Introduction

Research, being a systematic process, follows some important steps. Before actually conducting the research, it is necessary to have a bird view of the studies conducted in the same area or the studies related to the study undertaken. Research cannot be undertaken in isolation from the work that has already been done on the problems related to the proposed study. It is a pre-requisite for every researcher to learn what studies have been already undertaken in that particular area. Considering the knowledge which has been so far accumulated is very important. It means to go through the earlier documents and research reports which are related to the problem under investigation. Review of related literature implies locating, reading and evaluating reports of research as well as reports of casual observation and opinion that are related to the individual‘s planned research project. It involves careful review of research journals, books, dissertations, theses and other sources of information. This review forms the foundation upon which the researcher‘s work will be built. It helps in developing an insight into the problem under investigation and to accumulate the past studies and go through the up to date works in the field. The already existing body of knowledge helps us a lot to further investigate problems.

The researcher picks up clues for creating or evaluating his own design from the reports of previous researches and arrives at a more comprehensive group of related aspects of the topic. A familiarity with the literature in any problem area helps the researcher to understand what is already known; what others have attempted to find out; which methods or approaches have been promising or disappointing and what problems remain to be solved or studied. In the words of Good **(1952),** the key to the vast store house of published literature may open doors to sources of significant problems and explanatory hypothesis, provide helpful orientation for definition of the problems, background for selection procedure and comparative data for interpretation of results.

This chapter constitutes the reviews of the studies related to the present study. The studies have been divided into six sections—the first section contains the studies directly related to cognitive science and the other five sections are divided according

to studies conducted on the components of cognitive science under study, i.e. attention, creativity, intelligence, learning and problem solving.

(1) studies on cognitive science
(2) studies on learning
(3) studies on problem solving
(4) studies on creativity
(5) studies on intelligence
(6) studies on attention

Studies on Cognitive Science

Glaser (1988) in his paper **"Cognitive science and education"** agrees that cognitive science offers a re-conceptualization of the nature of the learning process and new approaches to the investigation of learning. He believes that now detailed methods exist for inferring mental processes from empirical data. Growth of information-processing theory also offers an important tool for theory building in the domain of complex intellectual processes. The relevance of cognitive science for education has grown as it has tackled more of the complex activities of everyday cognition and of formal areas of human competence. In their early forms, information processing studies, particularly on problem solving, accepted the tradition of early experimental psychology; they explored knowledge-lean problems and concentrated on the basic and general information-processing capabilities people use when they behave more or less intelligently in situations where they lack any specialized knowledge and skill.

Leong (1993) argues in the paper **"Towards an applied cognitive science perspective in education"** for the role of an applied cognitive science perspective in education. The paper outlines the nature of cognitive science, and discusses the relevance and inadequacy of the brains metaphor and the computing metaphor. It states that the concept of parallel distributed processing, bolstered by the social construction of knowledge, provides powerful frameworks for the teaching and learning of basic school subjects.

Cobb's (1997) "Cognitive science, instructional design, and teaching" is a review of the article of Griffin and Case. It provides a comprehensive overview of their research program. In doing so, they describe their efforts to improve the quality of

children's mathematical learning and frame their work as a paradigmatic illustration of the potential contributions of cognitive science to educational reform. According to the researcher, they succeed in demonstrating "that educational programs and practices that are grounded in cognitive science theory and research can be highly effective in improving children's mathematics learning and achievement". Though in his paper, he has not interfered in the specific details of Number Worlds program of Griffin and Case. Instead he tried to further clarify what cognitive science can and cannot contribute to current reform efforts by building on their arguments.

Kruse (1998) reports on the implications of brain research on education in the article **"Cognitive science and its implications for education."** The researcher gives details on how the brain works; information on the structure of the brain and an in-depth look at human learning in relation to the brain. Before the concluding remarks, it has been discussed what evidences suggest regarding cognitive processing.

Crane & Richardson (1999) provides an overview of the "cognitive revolution" and recent work on the brain, and then discusses the dominant strains within cognitive linguistics, arguing for wider applicability to literary theory and criticism in their article **"Literary studies and cognitive science: Toward a new interdisciplinary"**. They argue that cognitive sciences offer new paradigms for rethinking the relations among culture, linguistic activity, and agency.

Kala, & Ramadas (2001) carried out a study on **"History and philosophy of science, cognitive science and science education"** in which they reviewed some research relating philosophy of science and cognitive science with science education. They discussed research trends under two categories: domain-specific issues related to the conceptual content of science (conceptual structure, conceptual change, constraints to learning, cross cultural studies, language) and domain general related to conceptualization of science-epistemological studies (nature of science, studies in reasoning and scientific thinking, coordination of theory and evidence). They pointed out that since 1960s, science education research and curriculum development have been subtly or explicitly influenced by theories of learning. When, by 1970s, Piagetian stage theory was found inadequate, philosophy of science, gained currency in science education. Developments in cognitive science were also found to contribute towards research paradigms and methods, including expert novice studies, problem

solving and linguistic analysis. The authors argue that an awareness of these trends might help avoid scienticism in science education, that the philosophy of perception and representation might guide research work in the tradition of situated cognition.

Halpern (2002) shows that educational reform efforts should keep the knowledge about how people think, learn and remember in the centre in the paper **"Cognitive Science and the Work of Reform"**. It suggests against lectures, "canned" laboratory work, and frequent testing. Knowledge about human cognition can enhance how much and how well students can learn, which can be used to redesign higher education. The paper talks about the gap between empirically validated theories and pedagogical practice. Lecture method, mostly used in college level courses has been identified as appropriate for recognizing a concept, not to understand or apply the concept in other setting. It has been found that cognitive psychology and learning theory have much to offer in guiding how higher education is designed and reformed.

Croy (2002) explores pedagogical innovations that may be necessitated by the recent changes in the aims and methods of the philosophy of mind in **"Philosophy of Mind, Cognitive Science, and Pedagogical Technique"**. He describes computer simulations in particular which have emerged as a means of constructing empirically and conceptually defensible theories of mind. One question raised is whether hands-on teaching of simulation methods should be a standard part of philosophy of mind courses. These courses, because of an increasing empirical orientation, are becoming more interdisciplinary, and certain consequences of this development are elaborated in the paper.

Siegler (2003) in his study **"Implication of cognitive science research for mathematics education"** draws conclusions about a number of aspects of mathematics learning. It examines conclusions based on cognitive science research on some aspects of mathematics learning. The work informs us regarding how children typically learn particular skills and concepts, the stumbling blocks that many of them encounter, and instructional practices that can produce greater learning. It advocates that successful teaching and learning depends on careful, detailed, analysis of the particulars of individual children learning particular skills and concepts as well as the particular procedures and concepts to be learned. Some of the pedagogical implications which can be drawn from the study are—understanding what children

already know when they enter school, providing students with instruction and examples that help them learn the component skills, anticipating types of misunderstandings that most often arise in the learning process, helping students move beyond these misunderstandings, retaining cognitive variability (spontaneous feature of children's thinking), providing flexibility of choosing the strategy, attending to children‘s nonverbal gestures as well as their verbal statements as indicators of their understanding and readiness to learn, attending to both cognitive and social variables (for co-operative learning), asking children to explain both why correct answers are right and why incorrect answers are wrong, etc.

Klahr & Li (2005) conducted a study on **“Cognitive Research and Elementary Science Instruction: From the Laboratory, to the Classroom, and Back”.** They stated that cognitive research can generate usable knowledge for elementary science instruction and that issues raised by classroom practice can drive the agenda of laboratory cognitive research. They discuss five studies of the teaching, learning, and transfer of the ‒control of variables strategy‖ in elementary school science. The study begins from basic theoretical questions to subsequent inquiries within authentic educational debates—contrasting hands-on manipulation of physical and virtual materials, evaluating direct instruction and discovery learning, replicating training methods in classroom, and narrowing science achievement gaps. They suggest that those engaged in discussions about implications and applications of educational research focus on clearly defined instructional methods and procedures, rather than vague labels and outmoded ‒-isms.‖

Ansari & Coch (2006) presents the recent growing interest in and debate about the relation between cognitive neuroscience and education in **“Bridges over troubled waters: education and cognitive neuroscience”**. The authors aim at advancing the debate beyond both recitation of potentially education-related cognitive neuroscience findings and the claim that a bridge between fields is a wild fantasy. In an attempt to begin a dialogue about mechanisms among students, educators, researchers and practitioner-scientists, they propose that multiple bridges can be built to make connections between education and cognitive neuroscience, including teacher training, researcher training and collaboration. They argue that these bridges – concrete mechanisms that can advance the study of mind, brain and education – will

benefit both educators and cognitive neuroscientists, who will gain new perspectives for posing and answering crucial questions about the learning brain.

In their paper, **"Principles of cognitive science in education: The effects of generation, errors, and feedback"**, **Metcalfe & Kornell (2007)** found that principles of cognitive science hold the promise of helping children to study more effectively, yet they do not always make successful transitions from the laboratory to applied settings and have rarely been tested in such settings. The studies reviewed here address three interlocking questions in an effort to better implement a computer-based study program to help children learn: (1) Does generation help? (2) Do errors hurt if they are corrected? and (3) What is the effect of feedback? The findings reveal that generation helps, errors that are corrected do not hurt; and feedback is beneficial in verbal learning. These answers may help put cognitive scientists in a better position to put their well-established principles in the service of children's learning.

Schunn (2009) in the paper **"How kids learn engineering: The cognitive science perspective"** argues that age is not a bar to learn engineering. What is necessary is proper environmental support. He stated four principles which support engineering learning. These are—engaging children in solving significant design problems from the beginning, making visible models to support design task, iterative design and redesign are better than single design cycles and providing sufficient time for exposure to engineering material.

Aykol, Sungur & Tekkaya (2010) examine the differences in the level of 7th-grade Turkish students' cognitive and metacognitive strategy use in science in the paper **"The contribution of cognitive and meta cognitive strategy use to students' science achievement"**. It also explores the relationships between students' background characteristics (gender, prior knowledge, socioeconomic status) and their cognitive and meta-cognitive strategy use and science achievement. The statistical analyses revealed significant differences in the level of students' cognitive and meta-cognitive strategy use scores. Besides, elaboration, organization, and meta-cognitive self-regulation strategy use were found to make a significant contribution to students' science achievement. Moreover, prior knowledge, parents' educational level, number of reading materials at home, frequency of buying a daily newspaper, presence of a separate study room, and presence of a computer with internet connection at home

were significantly associated with cognitive and meta-cognitive strategy use and science achievement.

Roebers, Schmid & Roderer (2010) in their study **"Metacognitive monitoring and control processes involved in primary school children's test performance"** examine metacognitive monitoring and control processes in elementary schoolchildren's test taking behavior and explore the impacts of these meta cognitive skills for the accuracy and the quantity of test performance. Results reveal well-developed monitoring skills indicating that by the age of 9 children can reliably distinguish between correct and incorrect answers. As for control skills, 11- and 12-year-olds proved to be better able to improve their test performance by selectively withdrawing answers that would have been incorrect than the 9- to 10-year-olds. The study offers evidence for the impact of meta-cognitive processes in students' learning outcomes and documents strategic behavior during test taking, as well as developmental progression in the involved skills.

Tytler & Prain (2010) in their paper **"A Framework for Re-thinking Learning in Science from Recent Cognitive Science Perspectives"** states that recent accounts by cognitive scientists of factors affecting cognition imply the need to reconsider current dominant conceptual theories about science learning. These new accounts emphasize the role of context, embodied practices, and narrative-based representation rather than learners' cognitive constructs. In this paper they analyze data from a longitudinal study of primary school children's learning to outline a framework based on these contemporary accounts and to delineate key points of difference from conceptual change perspectives. The findings suggest this framework provides strong theoretical and practical insights into how children learn and the key role of representational negotiation in this learning. They argue that the nature and process of conceptual change can be re-interpreted in terms of the development of students' representational resources.

Studies on Learning

King (1994) carried out the study on **"Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain".** Following teacher-presented science lessons, pairs of fourth and fifth-graders studied the material by asking and answering each other‘s self-generated questions. In one

condition, students‘ discussion was guided by questions designed to promote connections among ideas within a lesson. In a second condition discussion was guided by similar lesson-based questions as well as ones intended to access prior knowledge/experience and promote connections between the lesson and that knowledge. All students were trained to generate explanations (one manifestation of complex knowledge construction). Analysis of post-lesson knowledge maps and verbal interaction during study showed that students trained to ask both kinds of questions engaged in more complex knowledge construction than those trained in lesson-based questioning only and controls. These findings, together with performance on comprehension tests for material studied, support the conclusion that, although both kinds of questions induce complex knowledge construction, questions designed to access prior knowledge/experience are more effective in enhancing learning.

Ivie (1998) advocated in the study **“Ausubel’s learning theory: An approach to teaching higher order thinking skills”** that developing thinking skills in students requires specific instruction and practice rather than application. Teachers should address analysis, evaluation and synthesis using advance organizers that encourage students to operate at higher levels of abstraction. Strengthening cognitive structures helps students retain information longer, and subsumptions provide students with basic structures on which to build new concepts.

Penuel’s (1999) paper **“Designing learning: Principles and technologies”** is based on the premise that workplace learning can be designed and that innovative organizations can take principles from the cognitive science of learning and use them to organize their own company‘s training and development projects. The paper reviews some of the key principles of cognitive science of learning as they can be observed in the way people think and act in different workplace activities. The principles involved are—learning takes place within communities of practice; novices learn to become experts through practice in solving a variety of problems in a domain; becoming an expert means applying learning to new contexts; prior knowledge mediates learning; learning is advanced when thinking is made visible by collaboration and reflection among learners.

Clump (2005) in his study **"Changes to students' learning processes following instruction on the topic"** investigated the effect of teaching students about effective learning processes in general to determine if this would alter their learning processes. Twenty-six Cognitive Psychology students completed the Inventory of Learning Processes one week before and one week following instruction on the topic of effective learning processes. The students' scores on the Deep Processing and Elaborative Processing subscales significantly increased from before instruction to after instruction, which is substantial given the significant relations between scores on these subscales and academic achievement.

Whiteley (2006) in the study **"Using the Socratic method and Bloom's taxonomy of cognitive domain to enhance online discussion, critical thinking, and student learning"** addresses the issue of implementing Socratic Method and Bloom's taxonomy of cognitive domain in Virtual Classroom Setting (VCS). The application of the Socratic Method can help the students in a step-by-step fashion, to acquire a higher-level learning (analysis, synthesis and evaluation). In this method, the role of the instructor is to assess the situation, direct the student in the right direction, but without providing the answers. This approach reflects scaffolding, providing a certain degree of assistance to guide the student. The teacher has to empathize with the students by understanding the problems faced by them during the learning process and to gradually guide the students to a proper understanding of the subject area. This method develops critical thinking and reflective thinking in the students. Throughout the application of the Socratic Method, the course facilitator needs to be aware of the level of learning that is relevant. Since the Socratic approach focuses on the area of critical thinking, it is, thus, an approach that can effectively be used to help students to achieve the higher-order learning level of Bloom's Taxonomy of cognitive domain. It has been found in the study that incorporating the Socratic Method in VCS as a means to develop critical thinking skills of students would provide a sound pedagogical foundation or model in VCS. The author has also suggested VCS can serve in a support role in a TCS to increase the effectiveness of TCS.

Rittle-Johnson & Star (2007) conducted the study entitled **"Does comparing solution methods facilitate conceptual and procedural knowledge? An experimental study on learning to solve equations"**. According to them, encouraging students to share and compare solution methods is a key component of

reform efforts in mathematics, and comparison is emerging as a fundamental learning mechanism. To experimentally evaluate the effects of comparison for mathematics learning, the authors randomly assigned 70 seventh grade students to learn about algebra equation solving by either (a) comparing and contrasting alternative solution methods or (b) reflecting on the same solution methods one at a time. At posttest, students in the compare group had made greater gains in procedural knowledge and flexibility and comparable gains in conceptual knowledge. These findings suggest potential mechanisms behind the benefits of comparing contrasting solutions and ways to support effective comparison in the classroom.

The purpose of **Brown Leonard (2008)** in the study **"Integrative learning as a developmental process: A grounded theory of college students' experiences in Integrative studies"** was to learn how students in an explicitly integrative learning environment make meaning of and understand integrative learning. Keeping consistency with the constructivist grounded theory methodology, the researcher developed an emerging theory about students' experiences with integrative learning that is grounded in the data. 10 students enrolled in an Integrative Studies Programme were interviewed. The students defined integrative learning very broadly. To capture the range of learning described by students, a continuum of different forms of integration that vary by complexity, application, comparison, understanding, context and synthesis was created. Students engaged in the least complex form of integration, application, by finding their coursework personally relevant and applying what they learn to their own lives. Through class discussion and reading students identified multiple perspectives, which led to integration as comparison. When different perspectives are in conflict, students began to engage in integration as understanding context. By reconciling conflict, students may reach the most complex form of integration synthesis.

Belenky, D. M. & Nokes, T. J. (2009) in their paper **"Examining the Role of Manipulatives and Metacognition on Engagement, Learning, and Transfer"** investigates the nature of students' learning of math concepts when using manipulatives. We examined how the type of manipulative (concrete, abstract, none) and problem-solving prompt (metacognitive or problem-focused) affect student learning, engagement, and knowledge transfer. Students who were given concrete manipulatives with metacognitive prompts showed better transfer of a procedural skill

than students given abstract manipulatives or those given concrete manipulatives with problem-focused prompts. Overall, students who reported low levels of engagement showed better learning and transfer when getting metacognitive prompts, whereas students who reported high levels of engagement showed better learning and transfer when getting the problem-focused prompts. The results are discussed in regards to their implications for education and instruction.

Jacobs & Shams (2010) in their paper **"Visual Learning in Multisensory Environments"** claimed that multi-sensory environments are useful for visual learning because non-visual percepts can be processed to produce error signals that people can use to adapt their visual systems. This hypothesis is motivated by a Bayesian network framework. The framework is useful because it ties together three observations that have appeared in the literature: (a) signals from non-visual modalities can ‗‗teach'' the visual system; (b) signals from non-visual modalities can facilitate learning in the visual system; and (c) visual signals can become associated with signals from non-visual modalities.

Gadgil & Nokes-Malach (2011) hypothesize that some classroom activities may afford benefits for collaborative learning over individual learning in their paper **"Overcoming collaborative inhibition through error correction: a classroom experiment".** They created a classroom writing activity that incorporated features such as shared prior knowledge and error-correction processes, which have been hypothesized to eliminate collaborative inhibition and to support constructive collaboration. Students participated in this activity either individually or in dyads. Results showed that the individuals who worked collaboratively performed equally well as those who worked individually and also showed better learning as measured by performance on a future writing assignment. They investigated whether it was possible to overcome the collaborative inhibition effect. They also examined whether collaboration can have facilitative effects on performance and learning, and whether these effects would depend on whether the task was a simple task or a complex task. We created a task to facilitate constructive collaborative interaction by adding the features of shared knowledge and error correction, which were hypothesized to reduce the cognitive costs of collaboration. The error correction task consisted of: error detection and revision, and for each component there were surface and structural errors that students could find or correct. Most importantly they found that those

students who had participated in dyads were significantly more likely to get correct the summary elements corresponding to their revisions of structural errors compared with those who participated as individuals.

Richland, Bjork, Finley & Linn (2005) in their paper **"Linking cognitive science to Education: Generation and Interleaving Effects"** Performance during a learning event is frequently used as a measure of learning; however, basic cognitive research suggests that this may be an unreliable predictor of long-term learning and transfer. Rather, in some training paradigms, higher error rates during training may predict greater retention and generalization of learning. One such paradigm is training in which learners generate, rather than read, during study opportunities. A second is training in which study for two sets of information is interleaved rather than grouped into separate blocks. Educationally relevant learning requires retention and the capacity to generalize information across contexts, leading to the hypothesis that these paradigms may have important implications for educational practice. An experiment is described in which the effects of generation and interleaving are examined using complex, educationally-relevant materials. Findings indicate that these effects are relevant for instructional design, but that there is not a straightforward relationship between laboratory research with simple materials and educational practice. Rather, the educational goal must be considered when determining the utility of generation and interleaving principles in designing instructional technology.

Yao (2004) in the study **–Concept Formation and Learning: A Cognitive Informatics Perspective".** Cognitive informatics aims at building machines and systems that simulate human ways of knowing and thinking. The study of concept formation and learning is central to cognitive informatics. The objective of this paper is to investigate basic issues of concept formation and learning from cognitive informatics perspectives. From the perspective of cognitive informatics, a layered framework is suggested for concept formation and learning. It combines cognitive science and machine learning approaches. The philosophical issues and various views of concepts are reviewed. Concept learning methods are presented based on the classical view of concepts. The philosophical level addresses questions about knowledge, the algorithm level concentrates on knowledge discovery methods, and the application level deals with the utility of the discovered knowledge.

Studies on Problem-Solving

Saxena (1980) carried out **"A study of children's problem solving and decision making strategies"** to investigate the possible strategies adopted by children in a sample problem solving and decision making situation. The findings revealed that in a problem solving situation the dead ends were overcome by the creation of sub-goals related to the final goal sates, the subjects in a decision making situation abandoned the goal itself. In a decision making situation, the interpersonal character of the situation where no strategy could be worked out without the co-operation of the partner, did not provide scope for the manifestation of total strategy or plans as made by the subjects. If the constraints of the interpersonal situation were made more relaxed, interspersed with no contingent gains and losses, the strategic manoeuvres were better understood.

Schoenfeld (1983) in the study **"Beyond the Purely Cognitive: Belief Systems, Social Cognitions, and Metacognitions as Driving Forces in Intellectual Performance"** explores the way that belief systems, interactions with social or experimental environments, and skills at the ―control‖ level in decision-making shape people's behavior in problem solving. It is argued that problem solvers' beliefs about what is useful in mathematics may determine the set of ―cognitive resources‖ at their disposal as they do mathematics. In other cases, individuals' reactions to an experimental setting may induce behavior that is almost pathological and at the same time, so consistent that it can be modeled. In general, such ―environmental‖ factors establish the context within which individuals access and utilize the information potentially at their disposal. The paper presents and discusses the protocols illustrating these points. He outlined a model based on an axiomatization of students' beliefs about plane geometry, and is shown to correspond closely to their problem-solving performance. He offered a framework for analyzing problem-solving performance at three qualitatively different levels: access to cognitive resources stored in Long Term Memory, executive or control decision-making, and belief systems.

Ross (2007) in his study **"Cognitive Science: Problem Solving and Learning for Physics Education"** presents three issues relevant to difficulty in problem solving: specialized systems of memory and reasoning; importance of content in thinking; and characterization of memory retrieval in problem solving. He states that because of the

different memory and reasoning systems, the processing may differ enough from prior learning to lead to lack of transfer. Students need to develop their ability to generate their own solution. Specific (content based) thinking influences the learning of abstract thinking. The paper also argues that the type of problem solving can often be understood in terms of the memory and cues. The representation of the problem with cues is critical and has huge influences on problem solving at least partly due to what knowledge is retrieved. Moreover, novices might be able to improve their problem solving by learning to do some more structural analysis and storing the results in memory.

Simone (2008) in the paper **"Problem-Based Learning: a framework for prospective teachers' pedagogical problem solving"** discussed that current educational reform movements emphasize preparing teachers for pedagogical problem solving in the classroom. This study examines the impact of problem-based learning on prospective teachers' problem-solving abilities. Two classes of prospective teachers were included in this study. The experimental class used problem-based learning while the control group used a more traditional approach. The dependent measure was the participants' analyses of a problem. The participants in problem-based learning were significantly better than the controls in constructing the central problem, elaborating the problem, relating their solutions to the problem, and using multiple resources. The results are promising because they give prospective teachers a powerful approach that fosters certain aspects of pedagogical problem solving. The implications of these results for prospective teachers are discussed.

Salden, Aleven, Renkl & Schwonke (2009) investigated a combination of two instructional approaches, tutored problem solving and worked examples in **"Worked Examples and Tutored Problem Solving: Redundant or Synergistic Forms of Support?"** Worked-out examples have been shown to be an effective complement to untutored problem solving, but it is largely unknown whether they are an effective complement to tutored problem solving. Further, while computer-based learning environments offer the possibility of adaptively transitioning from examples to problems while tailoring to an individual learner, the effectiveness of such machine-adapted example fading is largely unstudied. To address these research questions, one lab and one classroom experiment were conducted. Both studies compared a standard Cognitive Tutor with two example-enhanced Cognitive Tutors, in which the fading of

worked-out examples occurred either in a fixed way or adaptively. Results indicate that the adaptive fading of worked-out examples leads to higher transfer performance on delayed posttests than the other two methods.

Booth & Koedinger (2011) "Are diagrams always helpful tools? Developmental and individual differences in the effect of presentation format on student problem solving." This study was carried out to identify developmental and individual differences in the use of diagrams, story, and equation representations in problem solving. When do diagrams begin to aid problem-solving performance? Does the verbal advantage replicate for younger students? Two experiments were carried out for the study. In both experiments, students solved algebra problems in three matched presentation formats (equation, story, story + diagram). The textual advantage was replicated for all groups. The study yielded the result that while diagrams enhance performance of older and higher ability students, younger and lower-ability students do not benefit, and may even be hindered by a diagram's presence. The textual advantage is in place by sixth grade. Diagrams are not inherently helpful aids to student understanding and should be used cautiously in the middle school years, as students are developing competency for diagram comprehension during this time.

Mead, Nokes & Morrow(2012) in their paper **"The effect of expertise on collaborative problem solving"** found that collaborative success is a complex interaction of the prior knowledge and experience of the individuals working together, and the relation of their combined knowledge to the task (complexity level and task structure). This paper brings together multiple perspectives on what factors contribute to collaborative success by examining both learner factors (prior knowledge and experience in the domain) and contextual factors (task complexity). They aim to link this contextual perspective to a cognitive view by examining participants' prior knowledge and how that knowledge changes with experience in the domain. To understand collaborative problem solving, social theories must be anchored to cognitive approaches to get grip on the underlying knowledge representations and problem-solving mechanisms, and cognitive theories must move beyond individual cognitive analyses and consider interaction patterns as critical, irreducible, and fundamental to learning and performance of dyads and groups.

Limjap, A. A. (2002) in her paper, **"Issues on problem solving: drawing implications for a techno-mathematics curriculum at the collegiate level"** presented various issues about pedagogical and cognitive aspects of problem solving and explored ways to lessen the heavy cognitive load of a problem solving task. It established a problem type schema for students at different levels. It recognized the role of modern technology as a cognitive tool that promotes learning mathematics with understanding. It designed the framework of a techno-mathematics curriculum for algebra at the collegiate level.

Studies on Creativity

Prasad (1979) has reported the application of discovery method for teaching physics to high school pupils for promotion of creativity in the paper **–Promotion of Creativity and Achievement by Discovery Method"**. It was found that one of the basic abilities that should be taught in the schools is the ability to discover, to search answers instead of passively waiting answers and directions from the teacher. The results of the experimental study showed that the students taught by the discovery method showed significant improvement in achievement in achievement and creativity. For awakening the faculties of creative thinking in pupils, learning by discovery method should be encouraged. Therefore, pedagogy should emphasize the discovery of both problems and their solutions by the students themselves. If it is impressed upon pupils that there are many ways of reaching a solution to a given problem, they will then try to respond in a variety of ways to the same situation, thus preparing them for future creative action.

Sharma (1982) carried out a study on **"Factors Related to Creativity"** to explore the relationship of creativity with certain background, psychological and organizational factors of students of higher secondary schools of Delhi. It was found in the study that boys were more creative as compared to girls, scholastic achievement was positively related to the measures of creativity, creativity was significantly higher in the high I.Q. group in comparison to the middle and low I.Q. groups, and perception of teacher behavior by students was related to creativity in students.

Nandanpawar (1986) carried out an experimental study on **"Development of Linguistic Creativity among the Students"**. It was hypothesized that teaching through a creative method improves Marathi language proficiency of students,

develops linguistic creativity among students and develops such abilities as are involved in linguistic creativity as vocabulary, sentence construction, poem composition, story writing and imagination among the students. It was found that the experimental group scored significantly higher than the control group in (i) language proficiency, (ii) overall creativity, and (iii) all the abilities involved in linguistic creativity.

Torrance (1987) in his study **"Teaching for creativity"** summarized the results of 142 studies designed to test approaches to teach children to think creatively. It was found that the most frequently reported types of experiments are those that emphasize teacher-classroom variables, complex programs involving packages of materials, and modifications of the Osborn-Parnes training program in creative problem solving. Those having the highest percentages of success in teaching children to think creatively are those that emphasize the Osborn-Parnes training program, other disciplined approaches, the creative arts and media-oriented programs. It was concluded that the most successful approaches perhaps are those that involve both cognitive and emotional functioning, provide adequate structure and motivation, and give opportunities for involvement, practice and interaction with teachers and other children. Deliberate teaching is a significant factor in creative functioning.

Trimurthy (1987) carried out **"A Study of Creative Thinking Ability of Secondary School Students in the Context of Some Psycho-socio Factors"**. The objectives of the study were to design and construct reliable and valid verbal and nonverbal tests of creative thinking ability (CTA); to determine the extent to which sex, urban- rural location and grade influenced creative thinking ability; to study the trends of creative thinking ability in relation to age and I.Q.; to study the relation of test anxiety, self-sufficiency vs. dependency, socioeconomic status, leadership and emotional stability with CTA. The tests for measuring creative thinking ability were constructed and standardized. It was found that the variables like sex, area and I.Q. had their influence on CTA whereas other variables like test anxiety, self-sufficiency, dependency, leadership, emotional stability and SES did not exert significant influence on CTA.

Amin, M. J. (1988) conducted the research **"To Study the Effectiveness of Creative Thinking Programmes on the Creativity Level of the School Children in relation to the Programme Correlates"**. The objective of the study was to develop a creative

thinking programme (CTP) for enhancing the level of creativity in children with special reference to time duration for implementing the programme, teacher variability, discussion pattern in a group and programme correlates. It was found that there was significant effect of the creative thinking programme on creativity and its component measures: fluency and originality. The main effects of the two factors, time duration and group discussion, were found significant on creativity and fluency thinking ability. After the completion of every creative thinking programme, group discussion seemed to be worthwhile in terms of ideas produced.

Cole, Sugioka & Yamagata-Lynch (1999) conducted a qualitative study on **"Supportive classroom environments for creativity in higher education"**. They identified four areas as important characteristics of the supportive environment for fostering creativity—teacher-student relationship, assessment, degree of freedom, and classroom activities. It was found that personal teacher-student relationship, de-emphasizing standardized assessment, an open environment with freedom of choice and encouraging multiple perspectives was significant for developing creativity in the classroom.

Hamza & Griffith (2006) in the article **"Fostering problem solving and creative thinking in the classroom: Cultivating a creative mind"** put forth a discussion of the complex nature of creativity and shares the results of a one-year study conducted at a college in the state of Texas. In this study, the researchers explored teaching methods and instructional approaches, styles and methodologies that contributed into building creative learning environments in which creative thinking and problem solving skills were promoted.

McWilliam (2007) in the paper **"Is creativity teachable? Conceptualizing the creativity/ pedagogy relationship in higher education"** explored reasons for the growing interest in creativity as a learning outcome and elaborated key imperatives in the post-millennial ideational and policy context. The paper then moves to consider questions of the teachability of creativity and the pedagogical implications of this. Teachers and students act as co-creators of information products, drawing on a network of people and ideas that is fluid and organic. The pedagogical work, then, consists of mutual involvement of teacher and student in assembling and dissembling cultural products designed to inform, entertain, subvert, problem-solve and

investigate. The students need the capacity to edit reality—to organize it and re-organize it by mixing form and content, to juxtapose through display, to compare texts to understand their difference. It is the capacity to engage in value adding assembling and dissembling processes—not the ability to regurgitate content knowledge—that needs to be prioritized in any authentic regime of assessment for creative capacity building.

Basantia & Panda (2010) examined the effect of multi-dimensional activity-based integrated approach over traditional method of teaching in developing creative abilities among elementary school children through the subject in the study **"Development of creative abilities among elementary schools students through multi-dimensional activity-based integrated approach".**

Lin (2011) in the paper **"Fostering Creativity through Education—A Conceptual Framework of Creative Pedagogy"** identify capacities and qualities of creativity and proposed strategies in fostering children's creative thinking skills to create supportive environments in an educational setting. There is little consistent rhetoric, however, among these insights and strategies concerning different aspects of fostering creativity. In light of this, a three-element framework of creative pedagogy is proposed to offer a more holistic view of enhancing creativity through teaching, to cover the aspect of creative learning which was overlooked in the past, and to provide a different explanation to some arguments about teaching creativity. This framework is also a starting point for studies which intend to understand the teachers and pupils' responses to creative pedagogy, and to provide implications for applying creative pedagogy in a classroom and in Asian context as well. In the end, several possible routes are suggested for future research in creative pedagogy.

Studies on Intelligence

Fogarty (1998) in her paper **"The Intelligence-friendly classroom: It just makes sense"** provides guidelines that serve as a bridge between theory and practice in the intelligence-friendly classroom. She assumes intelligence to be emotional, nurturable, constructed, experiential, multiple, modifiable and elusive. Accordingly, it makes sense to provide emotional safety, create rich environments, provide tools for the mind, challenge through doing, target many dimensions, mediate learning and vary the ways to measure it. The article investigates the theoretical underpinnings of

intelligence-friendly classrooms briefly and their practical implications in more depth. Some guidelines have been developed which are derived from various theories of intelligence and have compelling classroom implications. These are—emotional safety and care for all learners; rich learning environment in which science equipment, art supplies, tools and workbenches, toys and building blocks, optical illusion posters, etc. are present; teaching of mind-tools and skills of life which include critical thinking skills, creative thinking skills, social skills, technological skills, visual skills, skills in the performing arts, and skills of the elite athlete; develop skillfulness of the learners through formal teaching-learning structures, independent readings, research, dialogue, discussion, articulations of peer coaching, mentoring, or internships and with experiences; provide challenges through experience of doing, i.e. inviting the learner to become an integral part of the teaching learning process; target multiple dimensions of intelligence, i.e. learning is structured in naturally integrated ways that call upon various intelligences; transfer learning through reflection; assessment measures should be balanced and integral to all other interactions.

Sternberg (1999) in the paper **"Successful intelligence: finding a balance"** argued that two extremes have prevailed in the study of intelligence. At one extreme are general-ability (*g*) theorists, who have collected large amounts of data to test the theory of general intelligence, but often using restricted ranges of participants, materials or situational contexts. They also show a tendency to limit their methods of data analysis (e.g. to exploratory factor analysis). At another extreme are theorists arguing for new, multiple intelligences, whose theories have been subjected to few or no empirical tests. He argues that a middle ground is needed that recognizes the multifarious nature of intelligence and of people's conceptions of it, but subject to rigorous empirical tests. The author talks about having firm footing with respect to the scientific basis of intelligence. This article places more emphasis on creative and practical abilities than others in the field.

Haier & Jung (2008) conducted **"Brain Imaging Studies on Intelligence and Creativity: What is the picture for education?"** The goal of the study is to summarize current brain research on intelligence and creativity that may be relevant to education in the near future. The paper addresses five issues: (a) Why is there a neuroscience interest in intelligence? (b) Can intelligence be located in the brain? (c) Why are some brains smarter than others? (d) What do we know about creativity and

the brain? and (e) Can information about an individual‘s brain structure and function be useful to benefit his or her education? Integrating neuroscience findings into education practices is a challenge that will require educators to reexamine old ideas and acquire fundamental backgrounds in new areas.

Watve (2010) studies the interrelationship between the eight intelligences assumed by Howard Gardner in the paper **“Multiple intelligences: Nature and interrelations”.** Almost all the correlations were found to be significantly high, except that between Linguistic and Interpersonal intelligences. Significant high correlations between Linguistic and Intrapersonal, but insignificant correlation between Linguistic and Interpersonal were revealed. Logico-mathematical appeared to be least correlated with others. Some probing into various such relationships is also discussed.

Tsai (2011) in the paper **“The meta-epistemology of knowing-how”** offers a meta-epistemology of knowing-how, including considerations of the subject matter, task, and nature of the epistemology of knowing-how. This aim is achieved by distinguishing varieties of knowing-how and by introducing and elaborating the concept of hybrid knowing-how, which entails a combination of ground-level ability and a meta-level perspective on that ability. He advocates that the epistemology of knowing-how is a normative discipline whose main task is to study the nature and value of human practical intelligence required to do things in a particular manner.

Studies on Attention

Tomlin & Villa (1994) examined in **“Attention in Cognitive Science and Second Language Acquisition”** how the cognitive notion of attention has been employed in Second Language Acquisition (SLA) and how it is understood in cognitive science. It summarizes recent research on attention from cognitive and neuroscience approaches. Current research offers detailed ideas about attention and its component processes. These ideas, elaborated theoretically and empirically in cognitive neuroscience, may help untangle some important but difficult issues in SLA. Early, coarse-grained conceptions of attention, such as the limited-capacity metaphor or the automatic versus controlled processing dichotomy, are recast into an integrated human attention system with three separate yet interrelated networks: alertness, orientation, and detection. This finer grained analysis of attention is employed in a model of the role of attention in SLA.

Hanauer (1999) carried out the study **"Attention and literary education: A model of literary knowledge development"** The aim of this paper is to describe the workings of one cognitive model for the development of literary knowledge. The central aspect of this model is the role of the systems of awareness and attention in developing the individual's ability to detect and internalize specific information from literary texts. The paper starts by defining literary education within the theoretical framework of the cognitive processes of control and analysis. This is followed by a model of the development of literary knowledge based on the central role of awareness and attention. Empirical evidence which is relevant to the assumptions and predictions of the model is then discussed. Finally, the implications of this model on literary education and recommendations for future research are presented.

Feil (2009) in his thesis **"Attention and encoding in physics learning and problem-solving"** presents several studies designed to probe the mental representations that physics experts and novices form when interacting with typical instructional materials, such as diagrams and problem statements. By using recognition tasks and a change detection task, the mental representations of experts and novices are studied in a more direct way than with tasks such as problem sorting or interviews. Results show that the experience and knowledge of physics experts influence the features of visual stimuli that they encode. The final study revealed that animating multimedia learning content can help to focus learner's attention towards relevant items on the screen and in some cases reduce cognitive load as well.

Srivastava (2009) carried out an experimental study on attentional blink in her study **"Time Course of Visual Attention"**. The objectives of the study are to understand the time course of shift of visual attention when attention is allocated to objects differently and to understand the explanations for attentional blink such as limited attentional resource or temporary loss of control. The study investigates the time course of shifts of visual attention modulated by different aspects of objects or object based information by manipulating emotion (happy and sad) and perceptual levels.

Baijal (2010) carried on the study **"Relationship between Attention and Consciousness"** with the aim to explore how information gets accessed when type of attention is varied. The goals were specifically stated as—to investigate the limitations in the amount of information that can be consciously accessed by different

types of attention, to investigate the rate of encoding (a consolidation) of information in working memory by focused and distributed attention and the nature of interferences when the central processing resources have to be shared between them, to examine the effect of attentional state on perceptual awareness.

Jang, Schunn & Nokes (2011) in their paper **"Spatially distributed instructions improve learning outcomes and efficiency"** have stated that learning requires applying attentional resources along with limited working memory to intrinsic, germane, and extraneous aspects of the learning task. To reduce the split-attention effect, spatially integrated learning materials are suggested instead of spatially separated materials. Recent work, however, has suggested a new distinction between two common formats of spatially separated displays: spatially distributed (multiple sources of information are placed side by side) versus spatially stacked (only one at the top is visible). With materials more typical of practice, the distributed-display instructions led learners to more efficient and fast learning and scored higher in the overall learning test. With materials more tightly controlled for spatial format per se, it was found that the benefit of the distributed instructions appeared to be associated with changes in cognitive load. It states that simply manipulating the spatial format of instructions, leaving learning task materials alone, may suffice to significantly improve both task performance and learning.

Aran-Fillippetti & Krumm (2013) in their paper **"Executive function and attention in school age children according to the behavioral profile rated by their teachers"** have concluded that individual variations in the attentional dimension would be associated with individual differences of cognitive performance and though data indicate that children with higher levels of inattention obtain a lower performance in attention and executive function tasks, it is important to clarify that, according to the present study, this fact does not imply the presence of cognitive deficit.

Summary

The review of the literature related to the present study has revealed that there are very limited studies on cognitive science. This may be attributed to its young age. The researcher found that most of the studies are relevant to neuroscience or conducted from the perspective of neuroscience. This fact is also supported by Gupta (2001),

which says that three dominant trends in cognitive science research can be discerned—neurobiology of cognition, human neurocognitive architecture and cognitive technology. This conclusion has been drawn on the basis of research reports in the journals, commentaries, review articles and discussion trends in several conferences, seminars and meeting of Cognitive Science Society. Some research articles have established the implication of cognitive science on different aspects of education like curriculum, instructional methods for specific subjects, etc. But there is dearth of doctoral (intensive) work on it. It was found that very less number of works have been conducted on the implications of cognitive science on pedagogy for attention (7 studies) and intelligence (5 studies). Feil (2009) studied the mental representations of experts and novices in a direct way by using recognition tasks and a change detection task and found that animating multimedia learning content can help to focus learner‘s attention towards relevant items on the screen and in some cases reduce cognitive load as well. Jang, Schunn & Nokes (2011) found that simply manipulating the spatial format of instructions, leaving learning task materials alone, may suffice to significantly improve both task performance and learning. Fogarty (1998) developed some guidelines which are derived from various theories of intelligence and have compelling classroom implications. Studies on cognitive science which are relevant to creativity (11 studies) and learning (12 studies) are more in number. For e.g., Hamza & Griffith (2006) explored teaching methods and instructional approaches, styles and methodologies that contributed into building creative learning environments in which creative thinking and problem solving skills were promoted. **Penuel (1999)** reviews the principles of cognitive science which can be used in organization. **Whitely (2006)** showed that use of use of Socratic Method and Bloom‘s taxonomy of cognitive domain in Virtual Classroom teaching for higher level learning. **Yao (2004)** investigates basic issues of concept formation and learning from cognitive information perspectives. Eight studies have been found on problem solving. **Ross (2007)** established that content-based thinking and representation of the problem with cues helps problem solving and **Limjap (2002)** explored ways to lessen the cognitive load of a problem solving task and recognized the role of technology for it. There are 16 studies which draw implications of cognitive science on education as a whole. For e.g., **Glaser (1988), Leong (1993)** and **Kala & Ramadas (2001)** advocated for the application of cognitive science principles in education.