CHAPTER - II

REVIEW OF RELATED LITERATURE

2.1 Studies related to Cognitive Acceleration Approach

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REVIEW OF RELATED LITERATURE

The review of related literature is a systematic, explicit and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners in a particular area of study (Fink, 2008). It forms the foundations upon which all future work will be built and also provides a sound basis for formulating research hypothesis. It promotes a greater understanding of the research problem and its crucial aspects and research methodology. It helps the researcher to identify what has already been done and what gets need to be done. Thus, by reviewing related studies and literature one is saved from the process of duplication or repetition.

In this study, the investigator made an attempt to investigate the effectiveness of the Cognitive Acceleration Approach over the existing Activity Oriented Method in improving (a) Thinking Skills in Chemistry (b) Attitude towards Science Learning and(c) Achievement in Chemistry. Therefore a careful analysis of related studies available on the proposed study is carried out and presented in this chapter under the following headings. Each review is followed by an overview of the studies.

- Studies related to Cognitive Acceleration Approach
- Studies related to Thinking Skills
- Studies related to Attitude towards Science Learning
- Studies related to Achievement in Chemistry
- Studies related to gender influence on the variables of the study

2.1 Studies related to Cognitive Acceleration Approach

Cognitive Acceleration Approach (CAA) established as Cognitive Acceleration through Science Education (CASE) in the early 1980s in United Kingdom. It was designed as an intervention programme in Science curriculum to produce long term gains in academic achievement by attempting to raise children's intellectual performance. Though originally applied in science, Cognitive Acceleration Approach has also applied in other subject areas such as Mathematics, History, technology and Arts. In all the cases the effectiveness of the
approach on cognitive development, higher order thinking skills and achievement in the corresponding subject were studied. Since the Cognitive Acceleration programme was originated in UK, most of the research studies related to CAA are conducted in UK. A few studies are reported from Pakistan, Malawi, Malaysia and Australia. The investigator made an extensive search for Indian studies on Cognitive acceleration approach but could not find any studies reported. A careful analysis of related studies available on Cognitive Acceleration approach is presented below.

Budiman, Halim, Mohd and Osman (2014) compared three teaching methods namely a Cognitive Conflict Management Module (CCM) that is infused into Cognitive Acceleration through Science Education (CASE), CASE without CCM and a conventional teaching method. This study employed a pretest-posttest quasi experimental design using nonequivalent control groups. The design involved 130 participants from Form 2 (Grade 7) in a Malaysian secondary school. The findings showed that a high dose of cognitive intervention in CASE activities within a short period has an effect on the cognitive development, science achievement.

McCormack, Finlayson, and McCloughlin (2014) studied the cognitive level profile of primary and secondary level students in Ireland. In response to the low numbers of students capable of formal operational thought, and in an attempt to address the lack of pedagogical linkage across the primary-secondary level transition in Ireland, the Cognitive Acceleration through Science Education programme was adapted for use in the final year at primary level and in the first year at secondary level. The results on cognitive development measures showed that the students who were taught the programme in primary and secondary levels made significant gains, when compared to the non-intervention group.

Oliver, Venville and Adey (2012) explored the effects of cognitive acceleration programme in science in regional Western Australia. The research was conducted for over two years as a case study in one school with students as they entered high school in Year eight. Findings showed that significant cognitive
gains were made, with concomitant improvement in the State-wide testing in science when participating students were in Year nine, aged 13 and 14.

Anna (2008) described the report of Cognitive Acceleration activities in one of the schools in North London. Cognitive Acceleration was introduced in this school approximately nine years ago with the intention of promoting and developing children’s mathematical thinking at a deep level. It is reported that the programme helped the children to think about their work and articulate their thoughts more.

A report of the implementation of Cognitive Acceleration in Mathematical Education in 12 primary schools under a local authority in London was published by Nicky (2008). The programme was an action research and work was undertaken to improve thinking skills in mathematics and positive results were observed. The participants showed a 3% increase over results in schools that did not participate in the project.

McCarthy (2007) described how the introduction of Cognitive Acceleration Approach supported school improvement. Few members of the teaching staff received regular training in the Cognitive Acceleration through Mathematics and teachers used these lessons in their Maths classrooms. The children undergoing instruction in those classes were interviewed and they opined that the thinking lessons helped them to develop skills to solve difficult Maths problems, perseverance and communication skills. Teachers who applied the CAA opined that they felt the CAA lessons enabled pupils to develop skills that they could transfer to daily Maths lessons. They also identified impact in terms of the social skills needed for communication and collaboration.

Mark (2007) reported a case study of the implementation of Cognitive Acceleration programme in a Secondary School. Cognitive Acceleration was introduced to afford the pupils the opportunity to work in different ways. The members of the Mathematics department used Lessons based on Cognitive Acceleration and positive results were observed.
Shayer and Adhami (2007) studied the effect of Cognitive Acceleration Approach among primary children. The results showed that relative intelligence can be increased and is not fixed, and that children can be led into collaborating with each other to the benefit of their own thinking.

Jon and Cathie (2007) reported a Cognitive Acceleration Intervention Strategy for History Mysteries, Creativity, Literacy, and Thinking Skills through History with ICT among 9-13 year old gifted and talented children. The major outcome was the development of an inclusive, contextualised accelerated education. All the gifted and talented identified pupils appeared able to rationalise their thinking and adopt a schema to solve the mysteries.

Christiana and Jon (2007) investigated teacher expectations from the implementation of a cognitive skills teaching programme on students’ academic performance. The research was conducted among 16 science teachers. The findings revealed that teachers perceived student attitudes to be positive towards the implementation of the programme, because of the intrinsic interest in the activities and the unpressured way of exploring scientific investigations.

Jemma (2007) found how Cognitive Acceleration through Mathematical Education helped the teachers to develop problem solving skills in mathematics. The results of the children taught through Cognitive Acceleration programme were found to be significantly higher.

May (2006) reported a case study of the application of Cognitive Acceleration to improve results in Mathematics. The study was conducted over a three year period. Lessons based on Cognitive Acceleration were introduced to one class in the school and then the department integrated Cognitive Acceleration lessons in their curriculum. The findings of the study showed improved results in Mathematics. The success of this project prompted the team to encourage more departments to review their curriculum.

Larkin (2006) studied the individual development of metacognition in two five year old children over an academic year as they engage in cognitive acceleration through science education programme CASE@KS1. Using
qualitative analysis and case study methods the study demonstrated how collaborative group work with small children affects the development of an individual’s metacognitive processing. The results showed that providing metacognitive experiences through cognitive acceleration is a good way to achieve development of metacognitive processing.

McLellan (2006) assessed the impact of Motivational Worldview on Engagement in a Cognitive Acceleration Programme. The study was longitudinal and employed a non-equivalent control group quasi experimental design. The differences in the change of motivation of students attending Cognitive Acceleration programme and the control group students were inspected. The results showed that the students in the experimental group attained greater cognitive gains than similar students at control group.

Lin, Hu, Adey and Shen (2003) studied the influence of Cognitive Acceleration through Science Education on Scientific Creativity of secondary school students. Although there was no statistically significant difference, the results indicated that the CASE programme did promote the overall development of scientific creativity.

Goulding (2002) interviewed twenty-one teachers involved in the Cognitive Acceleration in Mathematics Education (CAME) project, to investigate how the project was being implemented in their schools, their attitudes to the project, their understanding of the theory and their explanations for learning gains. Although attitudes were largely very positive, teachers also identified disadvantages and some resistance to the project. The teachers stressed some aspects of the learning theory much more than others and identified dispositional changes as the most likely explanation for performance gains.

Adey (2002) studied the effects of Cognitive Acceleration Programme among students aged about 5 to 6 years. The findings showed long-term effects on pupils' academic development and social development.

The case study of Monifieth High School, reported by Angus (2001) described how the school had developed and used Cognitive Acceleration
Approach aimed at developing thinking skills in the context of science. The lessons based on Cognitive Acceleration Approach were delivered at the rate of one every two weeks, over two years. It was found that the pupil achieved better results.

Iqbal and Shayer (2000) investigated Pakistani secondary school students' development of formal thinking with an intervention programme, using Cognitive Acceleration Approach. The study involved students of two private schools and one public school, in Pakistan. Students' Science and Mathematics achievements improved at the end-of-year examinations. Results showed that males' cognitive development was better than that of the females in the public school. Private school students had higher thinking abilities and science achievement than their public school peers.

Shayer, David and Adhami (1999) applied Cognitive Acceleration approach in Mathematics education among secondary school students and found that achievement of intermediate aims, increased classroom interactions and significant improvements in pupils' attainments in mathematics.

Gouge and Yates (1999) established the Arts Reasoning and Thinking Skills project to accelerate adolescent development towards high-order thinking skills, through the medium of drama, music and the visual arts, based on the intervention model that underpins the cognitive acceleration programmes. The results showed that the intervention enhanced the performance of students in processing more chunks of information through their involvement in arts.

Backwell and Hamaker (1998) conducted a study on the design and development of Cognitive Acceleration through technology education and their implications for teacher education. The findings showed that the intervention enhanced the performance of students in Design and Technology, Science and Mathematics.

Adey and Shayer (1994) designed Cognitive Acceleration as an intervention programme, to produce long term gains in academic achievement by attempting to raise the children's intellectual performance. At the end of the two-
year intervention period students showed significant improvements in cognitive development and science achievement. Later, the students in the experimental group showed average gains of one grade in Science, and slightly smaller gains in Mathematics and English in their General Certificate of Secondary Education examinations. This was evidence for both the accelerating effect of the strategy in science and for the transfer of thinking skills into other curriculum areas. Later using ‘value-added’ statistical methodology, the examination results of about 4,500 pupils were analysed and the authors were concluded that: (1) there is a long-term effect, three years after the end of the intervention (2) there is a transfer effect from science into other subjects.

**Overview of the studies related to Cognitive Acceleration Approach**

The studies on Cognitive Acceleration approach (Anna, 2008; Nicky, 2008; Jon & Cathie, 2007; Shayer & Adhami, 2007; McCarthy, 2007; Mark, 2007; May, 2006; McLellan, 2006; Adey, 2002; Angus, 2001; Gouge, 1999; Backwell & Hamaker, 1998; Adey & Shayer 1994) showed favourable results in terms of cognitive development, thinking skills, short term and long term gains in academic achievement and also for the transfer of thinking skills into other curriculum areas.

Though originally applied in Science, the Cognitive Acceleration Approach (CAA) has also been applied in Mathematics, History, Technology and Arts. One of the experimental studies (Lin, Hu, Adey & Shen, 2003) proved the long-term effect of CAA on Scientific Creativity.

Since the Cognitive Acceleration programme originated in UK, most of the studies are conducted in UK. Successful interventions of CAA have taken place in other countries like, Malaysia (Budiman, Halim & Osman, 2014), (McCormack, Finlayson & McCloughlin, 2014), Australia (Lorna & Trevor, 2012; Oliver, Venville & Adey, 2012; McCormack, 2009), Ireland and Pakistan (Iqbal & Shayer, 2000). The descriptive studies on CAA (Christiana & Jon, 2007; Goulding, 2002) revealed the positive attitude and interest of teachers towards the approach.
All the studies related to the Cognitive Acceleration Approach (CAA) were either case studies or intervention programmes which resulted in improvement in science and mathematics achievement, cognitive and thinking skills, metacognitive development, problem solving in mathematics, social development, communication skills and social skills and development of motivation. All the surveyed studies extended for one or more years as experiments including intervention programme. It was never investigated as a normal classroom teaching approach. There are no research evidences for the investigations on CAA in the Indian context. Therefore the investigator fascinated to know whether the CAA is beneficial for classroom teaching if the treatment period is limited to a short period.

2.2 Studies related to Thinking Skills

Thinking is a higher level mental activity and thinking skills are the habits of intelligent behaviour. There are different types of thinking and different taxonomies of thinking skills are available. The thinking skills selected in the present study are the skill of classifying, hypothesising, drawing inference, justifying and interpreting. Since these skills come under the category of critical thinking skills the investigator reviewed research studies related to thinking, logical thinking, critical thinking, analytical thinking and higher order thinking.

Gupta, Burke, Mehta, and Greenbowe (2015) compared the effect of Science Writing Heuristic (SWH) laboratory instruction approach with the traditional laboratory instruction in developing critical thinking abilities among college students. Results showed that students received traditional laboratory instruction scored significantly lower on various CT traits, suggesting the SWH-based laboratory instruction is valuable in promoting CT thinking skills of students.

Kettler (2014) compared the critical thinking skills of 45 gifted and 163 general education students of fourth-grade of Texas. It was found that i) gifted students outperformed general education students. ii) there was no evidence of
main effects or interaction effects for gender in measures of critical thinking within these samples.

Nargundkar, Samaddar and Mukhopadhyay (2014) explored the impact of guided problem based learning approach on critical thinking skills in a core business analysis course. Results of this study indicated that the guided problem based learning approach motivated learning and improved student performance significantly.

Shutimarrungson, Pumipuntu and Noirid (2014) developed and studied the effect of a model of e-learning by using Problem-Based Learning to improve thinking skills of students in Rajabhat University. The students participated in this study showed significant the development of their thinking skills.

Vachliotis, Salta and Tzougraki (2014) developed and validated assessment schemes for assessing 11th grade students' meaningful understanding of organic chemistry concepts, and thinking skills in the domain and explored the relationship between the two constructs. Results showed that students' thinking level within a science domain is significantly related to their meaningful understanding of relative science concepts.

Ching and Fook (2013) investigated the effects of multimedia based graphic novels on the critical thinking skills in history learning among 291 Secondary students in Malaysia. The results showed that multimedia based graphic novel learning environment is effective to enhance and facilitate students' critical thinking skills toward history learning.

Yong and Chui (2012) investigated the thinking styles of high achievers and normal achievers and examined whether the thinking styles based on Sternberg's theory of mental self-government could predict their achievement in science. Results showed that there were statistically significant differences in thinking styles between high achievers and normal achievers.

Yeh (2012) developed a co-creation blended knowledge management model to cultivate university students' critical thinking skills and to explore the underlying mechanisms for achieving success. Thirty-one university students
participated in this study. Findings showed that scaffolding university students through knowledge sharing, internalization, and co-creation processes in a blended knowledge management environment can effectively enhance their critical thinking skills.

Bradberry-Guest (2011) conducted a study to determine whether a computer-based program would significantly increase kindergarten students' acquisition of higher order critical thinking skills. The research question addressed whether a specific computer program significantly increased the ability of kindergarten students to answer why questions when compared to those that received typical academic instruction without the computer program. The results indicated that K students receiving the program scored higher on why questions when compared to those who did not.

Marin and Halpern (2011) compared explicit and imbedded instructional modes and assessed critical thinking with the Halpern Critical Thinking Assessment among high school students in the United States. The students receiving explicit instruction showed much larger gains than those in the imbedded instruction group.

Simon (2010) analysed the relationship between faculty's perceptions of three campus climate factors namely, participatory decision-making, staff freedom and work pressure, and their use of five critical thinking instructional techniques in the classroom. Results indicated participatory decision-making was directly related, staff freedom was inversely related, and work pressure was not related to faculty's use of critical thinking instruction in their classrooms.

McGuire (2010) investigated the effect of direct instruction in rhetorical analysis on students' critical thinking abilities, including knowledge, skills, and dispositions. The researcher examined student perceptions of the effectiveness of argument mapping; Thinker's Guides, based on Paul's model of critical thinking; and Socratic questioning. A mixed methodology teacher action approach with one-group pretest-posttest design was used. Research findings indicated that there
were no significant differences between the pretest and posttest scores for induction, analysis, and evaluation.

Ismail, Ngah and Umar (2010) conducted a study on the effects of mind mapping with cooperative learning on programming performance, problem solving skill and metacognitive knowledge among computer science students. The moderating variable was the students' logical thinking level with two categories: high logical thinking ability and low logical thinking ability. A quasi-experimental study with posttest-only control group method that employed a $3 \times 2$ Factorial design in the study. The findings of this study showed that mind mapping with cooperative learning method is preferred compared to cooperative learning and traditional methods in programming performance, problem solving skills, and metacognitive knowledge for students of all logical thinking levels.

Macpherson and Owen (2010) assessed the critical thinking ability of students in a graduate medical course. Students' critical thinking skills were assessed and the results showed that overall students retained consistent patterns of ability in critical thinking over the year. Students aged 30 and over were more likely to perform better on the tests than those aged under 30. In motivational terms, it was showed that students who had more highly developed critical thinking skills, and older students, conducted a more realistic effort/reward analysis and were less willing to put effort into a test that was not an assessable component of their medical school curriculum, than were other students.

Ibrahim and Mustafa (2010) determined the degree to which the primary curriculum complies with the aim of developing critical-thinking skills by collecting teacher opinions and it was concluded that the primary curriculum was prepared in compliance with the critical-thinking skills. It was recorded that the concerned curriculum adopted a student-centered approach in terms of the skills but the teachers did not receive sufficient in-service training to provide students with the critical-thinking skill.

Choy and Cheah (2009) evaluated teacher perceptions of critical thinking among students and its influence on higher education. The study revealed that
teachers did not seem to understand the requirements needed to cultivate critical thinking among students and their perceptions of critical thinking of students influence their behaviours in the classroom.

McMahon (2009) examined the relationship between students working in a technology-rich environment and their development of higher order thinking skills. The results indicated that there were statistically significant correlations between studying within a technology-rich learning environment and the development of students' critical thinking skills.

Schellens, Van, De and valcke (2009) conducted an experimental study on tagging thinking types in asynchronous discussion groups and their effects on critical thinking. The results suggested that tagging thinking types significantly promotes critical thinking in general and the critical thinking processes during problem identification and problem exploration, in particular.

Baildon and Sim (2009) investigated on Singaporean Teachers’ perspectives of Critical Thinking in Social studies. Using a case study research design and constant comparative method they explored the ways, how critical thinking was conceived by a group of Singaporean social studies teachers, constraints to critical thinking and teaching critical thinking in Singapore's schools. Findings revealed that three key tensions namely, exam culture, uncertainty about the results, and the issue of professional identity, were involved in teaching critical thinking.

Angeli and Valanides (2009) studied instructional effects on critical thinking, where undergraduate students randomly and equally assigned to four groups, namely three teaching groups namely, general, infusion, and immersion and the control group. Post hoc comparisons showed that the infusion and the immersion groups outperformed over the control group.

Korkmaz and Karakus (2009) studied the impact of blended learning model on student attitudes towards geography course and their critical thinking dispositions and levels. An experimental pattern with pretest-posttest control group was used in the study. Results showed that blended learning model
contributed more to student attitudes toward geography course, critical thinking dispositions and levels when compared to the traditional learning model. There was a positive correlation between student attitude toward geography course and their critical thinking dispositions and levels.

Sendag and Odabasi (2009) assessed influence of the online problem based learning approach, employed in an online learning environment, on undergraduate students' critical thinking skills and content knowledge acquisition. The pretest-posttest control group design was used in the study. The results indicated that learning in the online PBL group did not have a significant effect on the content knowledge acquisition scores but had a significant effect on increasing the critical thinking skills.

Phan (2009) investigated the relations between goals, self-efficacy, critical thinking and deep processing strategies through path analysis. The study examined these four theoretical orientations, from both cross-sectional and longitudinal perspectives. Results provided good support for the hypothesized structural relationships.

Mok (2009) conducted a case study to investigate the level of effectiveness of a critical thinking syllabus, issued by the education authority to secondary school English language teachers in Hong Kong. Classroom teaching and writing lessons of English language teachers were observed, analyzed and reported. The data revealed that the teachers constantly deprived their students of the time and space for critical thinking.

Butchart et al. (2009) conducted a study on improving critical thinking using web based argument mapping exercises with automated feedback. A simple software system that allows students to practice their critical thinking skills by constructing argument maps of natural language arguments was prepared and used in a single semester undergraduate critical thinking course. The course was evaluated using a standardised critical thinking test and revealed an improvement in critical thinking skills.
Bataineh and Alazzi (2009) evaluated perceptions of Jordanian secondary schools teachers towards critical thinking. The secondary school social studies teachers were interviewed regarding their perspectives of teaching critical thinking skills in their classrooms. The results showed that Jordanian secondary school social studies teachers are not familiar with the definition and teaching strategies of critical thinking; the Jordan ministry of education guidelines did not require teachers to teach critical thinking. In addition, teacher manuals for the state-required textbooks provide only detailed content information, with only minor references to teaching critical thinking.

Celuch, Black and Warthan (2009) conducted a study on the influence of attitudes, attitude strength, and normative beliefs on student self-identity as a critical thinker. Results showed that students with strong and positive attitudes regarding critical thinking have strong normative beliefs associated with the skill, and these beliefs, in turn, affect self-identity as a critical thinker.

Yeh (2009) in his experimental study, integrated e-learning into the direct-instruction model in order to enhance the effectiveness of critical thinking instruction among pre service teachers. The experimental instruction effectively improved the pre service teachers' critical-thinking ability as well as their professional knowledge and personal teaching efficacy concerning critical-thinking instruction.

DeLeng et al. (2009) developed and experimented an e-learning model to foster critical thinking on basic science concepts during work placements in higher education. Online discussions were explored in two case studies. It was concluded that the e-learning model was successful in facilitating critical thinking.

Burgess (2009) investigated the effect of WebCT tools, such as discussion board and chat on enhancing critical thinking and engagement among developmental reading students. Improvements were noted in both reading engagement and critical thinking skills by using these online tools.

Halil and Serap (2009) assessed the critical thinking skills of pre-service teachers in the blended learning environment. The method of the study was
pretest, posttest single group model. There was no significant difference between pretest and posttest results.

Liliana and Lavinia (2009) examined whether Romanian science school curricula open towards the development of school students’ critical thinking skills. The results showed that critical thinking, critical analysis and criticism are poor and the critical thinking skills are disproportionately represented in the curricula of the primary and secondary science education.

Burke and Williams (2009) studied the developmental changes in children’s understanding of Intelligence and thinking skills by using a sample of 75 children from four primary schools in central Scotland. Results showed that there were no age trends found in children's definitions of effective thinking and consequently no correlations found between children's views of intelligence and effective thinking.

Barak and Dori (2009) used embedded assessment to enhance higher order thinking skills among in-service science teachers. Findings indicated that the students' higher order thinking skills were enhanced in terms of their ability to pose complex questions, present solid opinions, introduce consistent arguments and demonstrate critical thinking.

Prasart and Benjaporn (2009) investigated the effectiveness index of inquiry-based teaching, to compare analytical thinking between before and after students had learned by inquiry-based learning activities, and to study learning satisfaction of second grade students after they had learned through inquiry method. Results revealed that inquiry-based learning activities promoted students in terms of both cognitive, analytical thinking, and learning satisfaction.

McLoughlin and Mynard (2009) analysed higher order thinking in online discussions. The study was carried out in a women's university in the United Arab Emirates. Discussion forum postings were analysed for evidence of higher-order thinking. The researchers found evidence of higher-order thinking processes. The results also supported the notion that the correct conditions need to be present in order for higher-order thinking to arise.
Malamitsa, Kasoutas and Kokkotas (2009) explored the effect of an approach of teaching science which incorporates aspects of history of science in developing Greek primary school students' critical thinking. The encouraging results regarding critical thinking skills development were supportive to the integration of aspects of History of Science in science courses.

Wang, Woo and Zhao (2009) investigated critical thinking and knowledge construction in an interactive learning environment. Seventeen students at National Institute of Education of Singapore, participated in this study. Their reflections and discussions were analysed by following a content analysis approach. Results showed that writing reflections had potential to promote critical thinking but, not all students thought critically. Knowledge construction in groups and in class discussions happened at lower levels.

Combs, Cennamo and Newbill (2009) conducted a project on developing critical and creative thinkers by using a conceptual model of creative and critical thinking processes. The goal of the project was to define critical and creative thinking in a way that would be useful for classroom teachers charged with developing such skills in their students. The authors conducted an extensive literature review to distill critical and creative thinking skills into teachable components. Based on their findings, the authors developed a model of critical and creative thinking that is accompanied by a table of skills, objectives, and references.

Phonguttha, Tayraukham and Nuangchalerm (2009) compared Mathematics learning achievement, attitude towards Mathematics, and analytical thinking abilities of grade nine students using the Geometer's Sketchpad Program as media and conventional method. The findings revealed that students who learned using organisation of activities by the use of the Geometer's Sketchpad Program as media had higher attitude towards Mathematics learning, Mathematics achievement and more analytical thinking abilities than those organisation of activities using conventional method.
Asuman and Ubuz (2009) investigated the effects of drama-based instruction on students' geometry achievement, geometric thinking level, attitudes toward mathematics and geometry, and retention of achievement, in comparison with traditional teaching. The sample involved 102 seventh grade students from a public school. Multivariate analyses of covariance revealed that drama-based instruction had a significant effect on students' achievement, retention of achievement, thinking level, and attitudes, regardless of gender, mathematics grade in previous year, and prior attitudes and thinking levels.

Friedel et al. (2009) explored the comparative effect of overtly teaching critical thinking and inquiry-based learning among undergraduate biotechnology students. The data exhibited significant difference between experimental and control groups giving evidence that overtly teaching for critical thinking improves students' critical thinking skills as opposed to using the inquiry-based teaching method.

Ozlem and Mustafa (2009) studied the effect of creative and critical thinking based on laboratory applications on creative and logical thinking abilities of prospective teachers. The investigation proved that the experimental group was more successful than the control group in terms of the logical thinking ability and creativity.

Al-fadhli and Khalfan (2009) investigated the impact of using e-learning models with the principles of constructivism to enhance the critical thinking skills of students in higher education institutions of Kuwait University and found that e-learning model was effective in enhancing critical thinking skills.

Hayes and Devitt (2008) studied classroom discussions with student-led feedback as a useful activity to enhance development of critical thinking skills. It was found that the intervention significantly increased critical thinking ability of non-native English speaking students as compared to native English speaking students.

Seker and Komur (2008) assessed the relationship between critical thinking skills and in-class questioning behaviours of English language teaching students.
The findings obtained, indicated that the questions asked by the students of the higher critical thinking score group are not questions that clarify unclear points, but questions asked out of curiosity, to remove the uncertainties, and to lead people to think profoundly. The students in the higher score group experienced thinking processes more intensively than the lower score group.

Grosser and Lombard (2008) studied the relationship between culture and the development of critical thinking abilities of prospective teachers. The study revealed that a considerable number of the sample of prospective teachers are not yet functioning on Grade 12 level with regard to the execution of critical thinking skills and the various cultural worlds of these prospective teachers have not prepared them for the execution of critical thinking abilities.

Burke and Williams (2008) investigated the effectiveness of teaching thinking skills explicitly to 11/12-year olds by infusing thinking skills into the curriculum. There were three intervention conditions: collaborative, individual and control. The effectiveness of the intervention was evaluated with a combination of standardised and study-specific pre- and post-tests. Results demonstrated statistically significant gains for both individual and collaborative learning conditions in a range of thinking skills. The greatest increase in performance was seen in the collaborative learning condition.

Stupnisky, Renaud, Daniels, Haynes and Perry (2008) examined the reciprocal-effects between critical thinking disposition and perceived academic control, and their comparative influences on academic achievement of first-year college students. Results revealed that perceived academic control have a stronger impact on students' grade point averages than critical thinking disposition.

Lombard (2008) studied on modeling critical thinking through learning-oriented assessment. The critical thinking abilities of teacher education students were measured and the research results obtained showed that there was a dire need to nurture learners' critical thinking abilities. The concept learning-oriented assessment was interrogated and it was indicated how learning-oriented
assessment could possibly contribute in developing students' critical thinking skills.

Sezer (2008) compared the effects of integrating critical thinking skills into a teacher preparation course in Mathematics by examining a control and an experimental group. Results indicated that emphasis on critical thinking, even in one course content, can have positive effects on students' attitudes.

Savich (2008) conducted an action research project on improving critical thinking in History. The research methodology consisted comparison of the inquiry method of teaching history with the lecture method. The research results demonstrated that when critical thinking skills were emphasised under the inquiry method, students achieved higher scores on tests, quizzes, and assignments and gained a deeper and more meaningful understanding of history.

Shamir, Zion and Spector (2008) explored the effect of peer tutoring, metacognitive processes and multimedia problem-based learning on critical thinking. Analysis of the discourse conducted during the tutoring session indicated that the tutors and tutees in the experimental groups exhibited greater depth of critical thinking, demonstrated in the higher quality of discourse ratio calculated, than did the tutors and tutees in the control group.

Teachers' reflections on fostering higher order thinking in science class were studied by Barak and Shakhman (2008). The findings highlighted a diversity among the teachers in four areas: meta-strategic knowledge of the concept of higher-order thinking; practical utilisation of instructional strategies related to fostering higher-order thinking in the classroom; beliefs about students' abilities to acquire higher-order thinking skills and self-perception regarding teaching towards higher-order thinking. Regarding the second area, only a minority of the teachers see the fostering of higher-order thinking as an important objective of teaching physics.

Salmon (2008) studied about promoting culture of thinking in the young child. The study took place in two schools where participating teachers documented children's work as part of their teaching. The documentation was a
key element to make children's thinking visible as they installed the culture and language of thinking in their classrooms. The findings of the study showed that thinking routines build up positive attitudes about thinking and learning.

Tony (2008) investigated Mathematics teachers’ interpretation of higher-order thinking in bloom’s taxonomy. Results indicated that mathematics teachers have difficulty in interpreting the thinking skills in Bloom’s Taxonomy and creating test items for higher-order thinking.

Zhou, Wang and Yao (2007) investigated Critical thinking of urban high school students in a Chinese city. Students' dispositions towards critical thinking and critical thinking skills were assessed. Results showed that the students' dispositions toward critical thinking were at an average level while their critical thinking skills were very low. There was no significant difference between students from science classes and arts classes in their critical thinking dispositions while science students have a higher level of critical thinking skills. Students from advanced classes had a higher level of the two components of critical thinking than their counterparts from general classes. There were no differences between male students and female students in both components.

Gafoor (2007) assessed whether present education favours executive and external styles of thinking at the expense of achievement in Science. The study attempted to find out the preferred functions of thinking and scope of thinking and its impact on achievement in physics among secondary school students in the State of Kerala, India. The research design was descriptive. Findings showed that the order of preference of thinking styles based on functions of thinking among secondary students are legislative, executive and judicial respectively. The study also revealed that though students with high internal style of thinking have higher grade in physics, and those with higher external style of thinking have lower grade in physics, these differences are not statistically significant.

Agnes, Patrick, Mike and Kwan (2006) compared the effects of problem-based learning and lecturing on the development of students' critical thinking among undergraduate nursing students of Hong Kong. Students' critical thinking
disposition was measured and individual interviews were also conducted to elicit the students' perceptions of their learning experience. Compared to lecture students, problem-based learning students showed significantly greater improvement in overall critical thinking disposition and subscale scores.

Suleyman (2005) studied the effectiveness of problem based learning in science teaching on development of logical thinking skills among the student teachers of Gazi University, Turkey. The study, a quasi-experimental one realised that student teachers’ logical thinking skills developed better in treatment group than in the control group.

Patrick, Leonard, Ernest and Amaury (1995) studied the factors which influence the development of students' critical thinking skills. This study estimated the relative and unique effects of curricular exposure, formal classroom and instructional experiences, and out-of-class experiences on changes in critical thinking. Students' classroom and out-of-class experiences both make positive, statistically significant, and unique contributions to gains in critical thinking.

Overview of the studies related to thinking skills

There are many experimental studies conducted to find out the effect of different models, approaches and strategies to develop Thinking Skills. All these studies revealed favourable results in improving critical thinking skills, problem solving skills, gains in grade performances and retention in various subjects. Such models and strategies include Science Writing Heuristic (SWH) laboratory instruction approach (Gupta, Burke, Mehta & Greenbowe, 2015), guided problem based learning approach (Nargundkar, Samaddar & Mukhopadhyay, 2014), model of e-learning by using Problem-Based Learning (Shutimarrungson, Pumipuntu & Noirid, 2014; Agnes, Patrick, Mike & Kwan 2006; Suleyman, 2005), multimedia based graphic novels (Ching & Fook 2013), co-creation blended knowledge management model (Yeh, 2012), computer-based program (Bradberry-Guest, 2011), mind mapping with cooperative learning (Ismail, Ngah & Umar, 2010), direct instruction in rhetorical analysis (McGuire, 2010), tagging thinking types in asynchronous discussion groups (Schellens, Van, De & Valcke, 2009), blended
learning (Korkmaz & Karakus, 2009), online problem based learning (Sendag & Odabasi, 2009), web based argument mapping exercises with automated feedback (Butchart et al., 2009), e-learning model (DeLeng et al., 2009; Al-Fadhli & Khalfan, 2009), WebCT tools (Burgess, 2009), embedded assessment (Barak & Dori, 2009) inquiry-based teaching (Prasart & Benjaporn, 2009), drama-based instruction (Asuman & Ubuz, 2009) and peer tutoring, metacognitive processes and multimedia problem-based learning (Shamir, Zion & Spector, 2008).

Vachliotis, Salta and Tzougkaki (2014) explored the relationship between students' meaningful understanding and thinking skills. Descriptive surveys on thinking skills (Hirose, 2009; McLoughlin & Mynard, 2009; Macpherson & Owen, 2010; Mok, 2009; McMahon, 2009; Baildon & Sim, 2009 & Ibrahim & Mustafa, 2010) revealed that the subjects possess moderate level of thinking skills. Evaluations of teacher perceptions on critical thinking skills (Bataineh & Alazzi, 2009; Liliana & Lavinia, 2009; Choy & Cheah, 2009) revealed that teachers did not seem to understand the requirements needed to cultivate critical thinking among students. Factors influencing critical thinking, such as self-efficacy and deep processing strategies were investigated (Phan, 2009; Burke & Williams 2009; Celuch, Black & Warthan, 2009; Stupnisky, Renaud, Daniels, Haynes & Perry, 2008) and the results provided good support for the relationships. Studies conducted on thinking skills and various classroom factors such as discussions, questioning behaviours and perceived academic control (Phonguttha, Tayrakham & Nuanchalerms, 2009; Hayes & Devitt, 2008; Seker & Komur, 2008; Patrick, Leonard, Ernest & Amaury, 1995) obtained significant results.

The results of descriptive studies showed that students possess only moderate level of thinking skills. They also revealed that teachers are not aware about the requirements to cultivate critical thinking among students. Studies conducted on thinking skills and various classroom factors such as discussions, questioning behaviours and perceived academic control obtained significant results. These results show the urgency of investigations to improve thinking skills and awareness about thinking among students and teachers.
More over many studies were reported which proved the efficiency of CAA on cognitive development and thinking skills as part of a long intervention programme to accelerate cognitive development. The investigator was curious to know the effectiveness of instruction based on CAA for a short term, viz, three months, have any effect on thinking skills.

2.3 Studies related to Attitude towards Science Learning

Lin et al. (2014) investigated the effect of science magic activities on student attitude to science. A quasi-experimental design was conducted to explore the combination of science magic with the 5E instructional model to develop learning materials for teaching a science unit about friction. The participants were recruited from among the students of a middle school in central Taiwan. Based on the results, it is concluded that combined teaching method involving science magic activities and the 5E instructional model is effective for developing learning materials for teaching, and that this method improves students’ attitude toward science.

Yakar and Baykara (2014) studied the effect of inquiry-based learning practices on the scientific process skills, creative thinking, and attitude towards science of preservice science teachers. The study followed an experimental quantitative analysis method with the single-group pretest posttest design. The results showed that inquiry-based laboratory practices improved the scientific process skills, creative thinking levels and attitude towards science experiments of pre-service science teachers.

Tosun and Senocak (2013) explored the effect of Problem-based Learning (PBL) on metacognitive awareness and attitude toward chemistry of teacher candidates with different academic backgrounds. The study was carried out on one group using both pre-and post-test experimental studies. The findings showed that PBL was more effective in developing metacognitive awareness levels of students with weak science background knowledge compared to those with strong science backgrounds. In addition, the findings showed that PBL was effective in
increasing the attitude positively toward chemistry of students with weak scientific backgrounds.

Van and Walma (2013) developed a valid and reliable instrument to measure the attitude of in-service and pre-service primary teachers toward teaching science (DAS). The theoretical underpinning of the DAS combined with the statistical data indicated that the DAS possesses good construct validity and that it proves to be a promising instrument that can be utilised for research purposes, and also as a teacher training and coaching tool.

Turkmen (2013) assessed Turkish elementary teachers’ attitude toward science and science teaching. The sample of the study, 138 in-service elementary level science teachers from a province of Turkey, was selected by a clustered sampling method. It was found that in-service elementary level science teachers had positive attitudes toward science and science teaching.

Chen and Chen (2012) compared the effect of an inquiry-based learning (IBL) to that of a problem-based learning (PBL) approach on learner performance, attitude toward science and inquiry ability among 7th-grade students. The results revealed that all students performed equally in science learning despite of the treatment groups. In terms of attitude toward science, the findings indicated that students who participated in IBL or PBL groups reported more positive attitudes toward learning science.

Ferreira and Trudel (2012) examined the impact of PBL on student attitude toward science, problem-solving skills and their perceptions of the learning environment. Forty-eight students in three regular high school chemistry classes participated in the study. Results based on student answers to a survey questionnaire, journal entries, approaches to solving a problem, and teacher classroom observations indicated a significant increase in students’ attitude toward science, problem-solving skills and positive views of the learning environment. The use of PBL also facilitated the development of a sense of community in the classroom.
Rukavina, Zuvic-Butorac, Ledic, Milotic and Jurdana-Sepic (2012) conducted a survey among school children aged 10 to 14 years, who participated in science or mathematics workshops to measure their interest and motivation towards science and mathematics. The results of the survey on students’ attitude towards science and mathematics after the workshop indicated that students accept demonstrations, applications and practical, hands-on experimentation, and that after this type of classroom activities they express positive attitude towards science and mathematics.

Belge (2012) investigated the effect of interaction between gender and grade level on secondary school students' attitude toward chemistry as a school subject. The sample was composed of 197 students across Grades nine to 11. Results indicated that the interaction effect between gender and grade level on students' attitudes toward school chemistry in terms of both enjoyment and importance dimensions were statistically significant.

Odom, Marszalek, Stoddard and Wrobel (2011) examined the association of middle school student science achievement and attitudes toward science with student-reported frequency of using computers to learn science and other classroom practices. Both attitude toward science and student-centred teaching practices were positively associated with science achievement, and student-centred teaching practice was positively associated with attitude toward science. Computer usage was found to have a negative association with student achievement, which was moderated by traditional teaching practices.

Alrehaly (2011) explored the manner in which parents' attitude toward science learning influences their children's attitude and the effect of ethnicity on attitude toward science learning. The results of this study showed that parental attitude toward science learning were influenced by both parents' early life experiences and their own early science learning experiences in school. Cultural, ethnic and social effects were found difficult to measure. The results of the study revealed that there are three major factors that could heavily influence student academic success in science across cultures and ethnicities: (a) parental attitude
toward science education (b) parental involvement in science education and (c) parents' social stratification.

Raved and Assaraf (2011) examined the influential factors underlying the attitudes of 10th-grade high school students towards science studies. The study was conducted through a qualitative research methodology, gathering data based on interviews. This methodology exposed the students' feelings, views and beliefs, and explored the characteristics of the factors influencing students' attitudes. Results indicated that the most significant influential factors are interpersonal interaction between teacher and student, the relevance and authenticity of the topics being studied, and the diversity of the teaching methods.

Welch and Huffman (2011) examined the impact of participating in an after-school robotics competition on high school students' attitude toward science. Results indicated that students who participated in a robotic competition had a more positive attitude toward science and science-related areas in four of the seven categories examined: social implications of science, normality of scientists, attitude toward scientific inquiry, and adoption of scientific attitude.

Kose, Sahin, Ergun and Gezer (2010) investigated the effect of cooperative learning on eighth grade students' achievement and attitude toward science. The participants were 68 students from two different eighth grade classrooms of an elementary school. The classrooms were selected randomly as the experimental group and the control group. The results of t-tests demonstrated that the students in the experimental group had better performance.

Julie and Dorothy (2008) explored the effects of Cognitive Acceleration in Science on both the thinking skills and motivation among primary school students. The research adopted a quasi-experimental non-equivalent control group design. Results supported the positive findings of the originators of the Cognitive Acceleration programme.

**Overview of the studies related to Attitude towards Science Learning**

The experimental studies conducted to examine the effect of different approaches, models and strategies (Tosun & Senocak, 2013; Chenand, 2012;
Ferreira & Trudel, 2012; Rukavina, Zuvic-Butorac, Ledic, Milotic & Jurdana-Sepic, 2012; Welch & Huffman, 2011; Kose, Sahin, Ergun & Gezer, 2010) revealed that the use of these approaches, models and strategies are effective in raising the attitude of students’ towards Science Learning.

The descriptive studies analysed the various factors influencing students’ attitude towards Science Learning (Alrehaly, 2011; Raved & Assaraf, 2011; Zeidan, 2010) and found parental attitude toward science education, parental involvement in science education, parents' social stratification, interpersonal interaction between teacher and student, the relevance and authenticity of the topics being studied, and the diversity of the teaching methods as the most significant influential factors.

The investigator could not find any study which examines the effect of Cognitive Acceleration Approach on the Affective domain outcomes except the study of Julie and Dorothy (2008) who explored the effects of Cognitive Acceleration in Science on both the thinking skills and motivation among primary school students.

2.4 Studies related to Achievement in Chemistry

Lopez, Shavelson, Nandagopal, Szu and Penn (2014) inspected the influences of a core set of factors (prior science achievement, knowledge structures, spatial ability, gender, and ethnicity) and their overall contributions to problem solving in organic chemistry using multivariate regression analyses. Results indicated that knowledge structures are key predictors of problem-solving performance and account for a significant proportion of the variation in students’ problem-solving scores.

Barthlow and Watson (2014) investigated the effect of process-oriented guided inquiry learning in high school chemistry versus traditional lecture pedagogy. Results showed that POGIL pedagogy, as opposed to traditional lecture pedagogy, resulted in fewer alternate conceptions related to the particulate nature of matter. Male and female students in the POGIL group posted better posttest scores than their traditional group peers.
Tatli and Ayas (2013) examined the effect of a virtual chemistry laboratory on student achievement among 90 students from three different ninth-grade classrooms. It was concluded that the developed virtual chemistry laboratory software is at least as effective as the real laboratory, both in terms of student achievement and ability to recognize laboratory equipment.

Sesen and Tarhan (2013) investigated the effects of inquiry-based laboratory activities on high school students' understanding of electrochemistry and attitudes towards chemistry and laboratory work. The results of the study indicated that instruction based on inquiry-based laboratory activities caused a significantly better acquisition of scientific concepts related to electrochemistry, and produced significantly higher positive attitudes towards chemistry and laboratory.

Merchant et al. (2013) investigated the potential of a three-dimensional virtual world, to enhance undergraduate students’ learning of a vital chemistry concept. A quasi-experimental pretest-posttest control group design was used to conduct the study. Analysis of covariance revealed no statistically significant differences between the two groups as a whole for any of the outcome measures.

Karacop and Kemal (2013) determined the effect of jigsaw cooperative learning and computer animation techniques on academic achievement of first year university students attending classes in which the unit of chemical bonding is taught within the general chemistry course. The study was carried out in three different groups. One of the groups was randomly assigned to the jigsaw group, the second was assigned to the animation group, and the third was assigned to the control group, in which the traditional teaching method was applied. The results indicated that the teaching of chemical bonding via the animation and jigsaw techniques was more effective than the traditional teaching method in increasing academic achievement.

Lopez, Nandagopal, Shavelson, Szu and Penn (2013) investigated on self-regulated learning study strategies and academic performance in undergraduate organic chemistry among ethnically diverse students. Study diaries, concept maps,
and problem sets were used to assess study outcomes. Findings showed that students engaged in four commonly used reviewing-type strategies, regardless of ethnic group affiliation. However, these common strategies were rarely associated with problem solving, concept mapping, or course performance. In addition, students seldom engaged in metacognitive and peer learning strategies.

McDermott and Hand (2013) investigated the impact on chemistry learning of the degree to which students embedded or integrated multiple modes of representation at the end of the unit writing-to-learn activities. A multi-case study approach, utilising quasi-experimental methodology involving intact high school chemistry classes taught by two different teachers was employed. Analysis of quantitative data indicated that significant positive correlations were found between writing characteristic measurements and end of unit assessment performance.

Tosun and Taskesenligil (2013) investigated the effect of Problem-Based Learning on undergraduate students' learning about solutions and their physical properties, and on their scientific processing skills. The quasi experimental study was carried out through non-equivalent control and comparison groups pre-post test design. The findings of the study revealed that PBL is more effective than conventional instruction in improving students' learning and scientific processing skills.

Tarhan, Ayyildiz, Ogunc and Sesen (2013) investigated the effects of jigsaw cooperative learning activities developed by the researchers on sixth grade students’ understanding of physical and chemical changes. A pre-test and post-test experimental design with a control group was used. Results showed that jigsaw cooperative learning instruction yielded significantly better acquisition of scientific concepts related to physical and chemical changes, compared to traditional learning. Students in the experimental group had a lower proportion of misconceptions than those in the control group, and some misconceptions in the control group were identified for the first time in this study.
Sesen and Tarhan (2013) investigated the effects of inquiry-based laboratory activities on high school students' understanding of electrochemistry and attitudes towards chemistry and laboratory work. The results of the study indicated that instruction based on inquiry-based laboratory activities caused a significantly better acquisition of scientific concepts related to electrochemistry, and produced significantly higher positive attitudes towards chemistry and laboratory.

Lou, Lin, Shih and Tseng (2012) explored the effects of three different forms of the multimedia teaching materials on the achievements and attitudes of junior high school students in a chemistry laboratory context. The findings of the study indicated that the video and animation have more significant effects on promoting students' learning achievements in a chemistry laboratory context than static pictures in terms of operating equipment, technical operation, experimental procedures, and observation performance.

Akkuzu and Akcay (2011) used analogical models and narratives to introduce and teach Grade 9 chemical covalent compounds. The results showed that experimental group was more successful than control group.

Perkins (2011) analysed the impact of a context-based teaching approach (STS) versus a more traditional textbook approach on the attitudes and achievement in chemistry. Though the STS approach students had higher attitude post scores, there was no significant difference between the STS and textbook students' attitude post scores.

Hailikari and Nevgi (2010) assessed the relationship between different types of prior knowledge and student achievement in an introductory chemistry course. The participants were 193 chemistry students from the University of Helsinki. The results indicated that the quality of prior knowledge is clearly reflected in the pace of completing the course and in the tendency to drop out of the course.

Lin and Chiu (2010) compared the characteristics and sources of students' mental models of acids and bases with a teacher's anticipations and explored some
possible explanations why motivated students might fail to learn from a subject-knowledgeable chemistry teacher. It was found that the teacher in the study made accurate anticipations of her students' mental models in the case of the high achievers but inaccurate anticipations of the low-achievers' mental models and the diverse sources influencing their mental models. In addition, the teacher incorrectly attributed the poor achievement of the low-achieving students to their intuition and underestimated the effects of her teaching on the achievement of these students.

Stamovlasis (2010) investigated the role of some psychometric variables, such as, logical thinking and the mobility-fixity dimension, on students' achievement in chemistry problem solving. Multiple regression analysis was used to analyze the data, which were taken from students in tenth grade of high school taking a compulsory course in chemistry. Three different techniques were implemented in order to support a linear model. It was suggested that only memory capacity and logical thinking were the significant predictors, even though all the correlation coefficients with achievement were statistically significant.

Lee and She (2010) studied the effect of combining conceptual change and scientific reasoning on improving students' conceptual change and scientific reasoning ability. One group of students had completed the course combining conceptual change and scientific reasoning. The other group of students received conventional instruction. Results indicated that the experimental group's students significantly outperformed the conventional group.

Rodrigues, Taylor, Cameron, Syme and Fortuna (2010) analysed the role of level, familiarity, language and taxonomy in questioning Chemistry. This paper reported data collected via an audience response system, where a convenient sample of 300 adults aged 17-50 pressed a button to register their answers for twenty multiple choice questions. The findings revealed that structuring multiple choice chemistry questions is complex.

Calik (2010) investigated the effectiveness of teaching methods based on a four-step constructivist strategy for teaching ‘solution chemistry’. A sample
consisting of 44 students was selected purposively from two different Grade nine classes in the city of Trabzon, Turkey. The findings suggested that using different methods embedded within the four-step constructivist-based teaching strategy enabled students to refute some alternative conceptions, but does not completely eliminate student alternative conceptions for ‘solution chemistry’.

Devetak and Glazar (2010) studied the influence of 16-year-old students' gender, mental abilities, and motivation on their reading and drawing ‘submicrorepresentations’ (SMRs), which is a powerful tool for identifying misconceptions of chemical concepts and for generating proper mental models of chemical phenomena in students' long-term memory during chemical education. A total of 386 secondary school students participated in the study. The results showed moderate, but statistically significant correlations between students' intrinsic motivation, formal reasoning abilities and chemical knowledge at submicroscopic level based on reading and drawing SMRs. The visualisation abilities were not statistically significantly correlated with students' success on items that comprise reading or drawing SMRs.

Frailich, Kesner and Hofstein (2009) investigated the effectiveness of a web-based learning environment in enhancing 10th grade high-school students' understanding of the concept of chemical bonding. The teachers in the experimental group were asked to implement activities taken from a website, all dealing with the concept of chemical bonding. The study incorporated both quantitative and qualitative research. These results concluded that the web-based learning activities which integrate visualisation tools with active and cooperative learning strategies provided students with opportunities to construct their knowledge regarding the concept of chemical bonding.

Uzuntiyaki and Aydin (2009) developed and validated chemistry self-efficacy scale for college students that can be used to assess college students' beliefs in their ability to perform essential tasks in chemistry. Three dimensions, self-efficacy for cognitive skills, self-efficacy for psychomotor skills, and self-efficacy for everyday applications were considered. Each dimension of the tool
had moderate and significant correlations with student chemistry achievement and differentiated between major and non-major students.

Elias (2009) studied the effectiveness of mathetics in achievement in Chemistry at higher secondary level. The experimental group was instructed through the programmed frames and control group through the conventional method by an expert. The scores achieved by pupils learning chemistry through programmed learning approach showed that it was superior to the conventional methods.

Devetak, Lorber, Jurievic and Glazar (2009) compared Slovenian year eight and year nine elementary school pupils' knowledge of electrolyte chemistry and their intrinsic motivation. The study explored the differences between eight-year elementary school pupils (before the curriculum reform) and nine-year elementary school pupils (soon after the curriculum reform) in Slovenia, as regards specific chemistry knowledge and motivation to learn chemistry. Altogether, 191 elementary school pupils participated in the study. The results showed that pupils of nine-year elementary school were not significantly better at chemistry knowledge test scores than eight-year elementary school pupils. Similar results were obtained when comparing intrinsic motivation.

Aldahmash and Abraham (2009) compared the influence of animated visuals with static visuals on college students' understanding of organic reaction mechanisms in chemistry. This study also focused on the relationship between students' achievement and spatial ability. The results demonstrated that students using animated visuals performed significantly better than students using static visuals, who in turn performed significantly better than a control group with respect to knowledge of organic reaction mechanisms. A positive correlation was found between students' spatial ability and their achievement in organic chemistry. The results also indicated that students with high spatial ability gain more by viewing the kinetic visualizations.

Amaral and vala (2009) in their research work added a peer mentoring program to an introductory chemistry course at a university and studied the
benefits to the mentors. Faculty instructors were responsible for the lecture while peer mentors handled the group problem-solving portion. Results showed that mentors earned higher grades, withdrew from chemistry courses at a lower rate, and took more courses in chemistry than their counterparts.

Seery (2009) studied the role of prior knowledge and student aptitude on performance in chemistry among undergraduates. Statistical testing showed that there were significant differences between the mean scores of students who had and those who had not prior knowledge of chemistry in semester tests and end of year 1 exams, with the former group obtaining higher scores. Correlational analysis showed a strong correlation between prior knowledge and exam performance, and allows for probing of the role of student aptitude.

Parkinson (2009) explored the effect of peer assisted learning support on performance in Mathematics and Chemistry. The second year students assisted the first year students in a carefully controlled condition. Prior to tutoring, the tutored and non-tutored groups were very evenly matched. However, after one semester of tutoring there were substantial and significant differences between the tutored and non-tutored students.

Caccitore and Sevian (2009) conducted a study to improve student performance in general Chemistry by transforming their general chemistry laboratory curricula to be inquiry-oriented. A single laboratory experience was the only difference between two comparison groups enrolled in the same general chemistry course with otherwise traditional labs. The results evidenced that student learning of chemistry content and skills were enhanced by a single inquiry laboratory experience.

Ozmen, Demircioglu and Coll (2009) compared the effects of concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base Chemistry. In the research design, two cohorts of students were compared. Student understanding of acid-base chemistry was evaluated and the analysis of the findings revealed statistically significant
differences between the intervention and traditional groups with respect to conceptual understanding.

In their research work Schwartz, Sadler, Sonnert and Tai (2009) related the performance of college students in introductory science courses to the amount of content covered in their high school science courses. The sample included 8310 students in introductory biology, chemistry, or physics courses in 55 randomly chosen U.S. colleges and universities. Students who reported covering at least 1 major topic in depth, for a month or longer, in high school were found to earn higher grades in college science than did students who reported no coverage in depth. Students reporting breadth in their high school course, covering all major topics, did not appear to have any advantage in chemistry or physics and a significant disadvantage in biology.

Uce (2009) used a conceptual change method for teaching the mole concept at college level. A pretest-posttest control group experimental model was used. The results demonstrated that the use of conceptual change method was more effective in promoting understanding of the mole concept compared to the traditional method.

Atasoy, Akkus and Kadayifci (2009) studied the effect of a conceptual change approach on understanding of students' chemical equilibrium concepts among tenth-grade students. The study was conducted in two classes of the same teacher with participation of a total of 44 tenth-grade students. A pre-test/post-test control group semi-experimental design pattern was used. The results showed that the conceptual change approach was statistically more effective than traditional instruction in terms of students' conceptual understanding.

Demircioglu (2009) examined whether the application of conceptual change texts are effective before or after the instruction on 10th grade students' conceptual understanding and alternative conceptions about acids and bases. The study was conducted with 76 tenth grade students from three classes of a chemistry course taught by the same teacher. The analysis revealed that the
differences between the results in both the experimental and control groups were statistically significant.

Lewis, Shaw, Heitz and Webster (2009) investigated the affective domain factors related to student success in general chemistry. A profile of students' self-concept in the general chemistry setting was created, the relationship between self-concept and success in the course was investigated and evidence was found for the impact of self-concept after taking into account a cognitive measure.

Su (2008) evaluated the instructional effects of a Chemistry course with integrated information communication technologies such as animations, static figures, PowerPoint bulletins, and e-plus software as chemistry texts with the aid of computer-based technology, on university students' learning and attitudes. The results indicated that students acquired a better understanding of targeted chemistry concepts during the multimedia courses and significant differences in attitudes toward chemistry and learning chemistry were detected.

Jurisevic, glazar, Pucko and Devetak (2008) studied the intrinsic motivation of pre-service primary school teachers for learning Chemistry in relation to their academic achievement. The study included 140 first-year pre-service primary school teachers. Their results showed that students were more or less equally motivated for chemistry as for any other subject, but that the intrinsic motivation falls as the level of abstraction in individual subjects, such as chemistry and mathematics, increases.

Chambers and Blake (2008) studied the effect of using a computer-based competitive learning system called LearnStar, as supplementary instruction in introductory chemistry courses. The students who were involved in LearnStar performed significantly higher on the three classroom exams, the cumulative final, and in their overall class grade when compared to the control group who had not received supplemental instruction.

Ozmen (2008) investigated the effect of computer-assisted instruction on conceptual understanding of chemical bonding and attitude toward chemistry. The study employed a quasi-experimental design involving 11 grade students. A
A statistically significant difference was found between groups in favour of the experimental group. Students from the experimental group were more successful in remediation of alternative conceptions.

Tastan, Yalcinkaya and Boz (2008) studied the effectiveness of conceptual change text-oriented instruction on students' understanding of energy in chemical reactions. The subjects of the study were 60, 10th grade students at a high school, who were in two different classes and taught by the same teacher. The results suggested that conceptual change text instruction enhances the understanding and achievement; however, there was no statistically significant difference between the experimental and control group in terms of students' attitude towards chemistry.

Toto and Booth (2008) experimented the efficacy of a novel tool, mini-lecture movies, in teaching Web based general chemistry. The analysis showed a marked improvement in student learning, as evidenced by a corresponding increase in homework and final exam scores.

Williams, Bland and Christie (2008) examined the effect of a blended learning approach to inorganic chemistry for improving student achievement and satisfaction. Results revealed that there was an improvement in performance compared to previous years and other core chemistry modules.

Gurses, Acikyildiz, Dogar and Sozbilir (2007) investigated the effectiveness of problem based learning in a physical chemistry laboratory course. The parameters investigated were students' attitude towards a chemistry laboratory course, scientific process skills of students and their academic achievement. The design of the study was one group pre-test-post-test. A statistically significant difference between the students' academic achievement and scientific process skills was found. No statistically significant difference was found at the students' attitude towards the physical chemistry laboratory due to the instruction based on problem based learning.

Ahmet and Adnan (2007) studied affective factors that influence chemistry achievement and the power of these factors to predict chemistry achievement. In this research, motivation and anxiety for Chemistry course of 819 high school
students attending 10 different high schools located in the city center of Mersin, were investigated. It was determined that while second grade students of high school have the highest motivation for chemistry course, first grade students possess the highest anxiety level for chemistry course, as well. Also, it was found out that the motivation and anxiety for chemistry lesson, is a significant predictor of chemistry achievement.

Senocak, Taskesenligil and Sozbilir (2007) compared the achievement of prospective primary science teachers in a problem-based curriculum with those in a conventional primary science teacher preparation program with regard to success in learning about gases and developing a positive attitude towards chemistry. The subjects of the study were 101 first year undergraduate students. The results showed that there was a statistically significant difference between the experimental and control groups in terms of students’ achievement and their attitude towards Chemistry.

Doymus (2006) investigated the effect of cooperative learning and individual learning methods on students' understanding of chemical equilibrium in a first-year general chemistry course. The results indicated that the cooperative learning group was more successful than the other.

Overview of the studies related to Achievement in Chemistry

The experimental studies conducted on different models and strategies (Tatli & Ayas, 2013; Sesen & Tarhan, 2013; Merchant et al., 2013; Karacop & Kemal, 2013; Lopez, Nandagopal, Shavelson, Szu & Penn, 2013; McDermott & Hand, 2013; Tosun & Taskesenligil, 2013; Tarhan, Ayyildiz, Ogunc & Sesen, 2013; Sesen & Tarhan, 2013; Perkins, 2011; Akkuzu & Akcay, 2011; Calik, 2010; Frailich, Kesner & Hofstein, 2009; Elias, 2009; Aldahmash & Abraham, 2009; Cacciatore & Sevian, 2009; Ozmen, Demircioglu & Coll 2009; Su & King-Dow, 2008; Chambers & Blake, 2008; Ozmen, 2008; Toto & Booth, 2008) showed positive and significant results in improving Achievement in Chemistry. The experiments related to conceptual change methods and texts (Lee & She, 2010; Uce, 2009; Atasoy et al., 2009; Demircioglu, 2009; Tastan, 2008), the
experimental studies conducted in peer mentoring, cooperative and peer assisted learning (Amaral & Vala, 2009; Parkinson, 2009; Doymus, 2006) also revealed positive and significant results in improving Achievement in Chemistry.

Descriptive studies conducted by (Hailikari & Nevgi, 2010; Lin & Chiu, 2010; Rodrigues, Taylor, Cameron, Syme & Fortuna, 2010; Stamovlasis, 2010; Lewis, Shaw, Heitz & Webster, 2009; Devetk, Lorber, Jurievic & Glazar, 2009; Seery, 2009; Ahmet & Adnan, 2007) analysed the influence of various cognitive and affective factors that influence achievement in chemistry like teacher's anticipations, prior knowledge and motivation of students and found significant relationships.

Though there are many research studies which experimented the effect of different approaches, models and techniques of teaching on Achievement in Chemistry, the investigator could not find any study which experiment the effect of Cognitive Acceleration Approach on Achievement in chemistry through the regular classroom teaching.

2.5 Studies related to gender influence on the variables of the study

Hudson and Treagust (2013) explored the relationship between performance in state university entrance examinations in chemistry and school chemistry examinations and student gender, format of questions--multiple-choice or short-answer, and conceptual level--recall or application? Results indicated that when overall mean data were considered, both male and female students performed better on multiple-choice questions and recall questions than on short-answer questions and application questions, respectively. When overall mean data were considered, male students outperformed female students in both the university entrance and school tests, particularly in the higher scores.

Chetcuti and Kioko (2012) investigated the attitude of secondary school girls towards science in the Eastern province of Kenya. The methodology included the use of both questionnaires and focus group interviews. The findings of the study showed that the majority of Kenyan girls had a favourable attitude towards science and their perceptions of the relevance of science, enjoyment of studying
science, suitability of science for a career, and subject difficulty were influential factors.

Desy, Peterson and Brockman (2011) conducted a survey of 6th-12th grade students to measure their science-related attitude and interests. Females reported more anxiety about science as well as less motivation in and enjoyment of science than males. In spite of their unfavorable attitude toward science, a large percentage of females expected to pursue a college major and subsequent career in the health sciences.

Zeidan (2010) investigated the relationship between the attitude toward Biology and perceptions of the biology learning environment among grade 11 students in Tulkarm District, Palestine and the effect of gender and residence on these variables. The results of the study indicated that i) association between attitude toward biology and the biology learning environment were significant. ii) there were significant differences with respect to gender, favouring females and no significant residence differences.

Lee, Teo and Chai (2010) examined pre-service teachers' knowledge and regulation of their own thinking. The results showed no significant difference by educational level on all subscales except for evaluation, which is a subscale of regulation of knowledge and no significant mean differences by gender. The results also indicated that the mean scores for all subscales were significantly different by teaching experience, except for monitoring and procedural knowledge.

Sibichen (2009) conducted a descriptive study on thinking skills of secondary teacher education students. The general objective of the study was to find out the level of thinking skills: critical thinking, creative thinking, logical reasoning, problem solving, decision making and lateral thinking. The significant differences were found out in the level of thinking skills of secondary teacher education students in terms of gender, subject specialisation, parents’ annual income status, graduate /postgraduate, attended / not attended a computer course.
and there were significant differences between graduate and postgraduate students in thinking skills.

Quitadamo, Braehler and Crouch (2009) examined the impact of peer-led team learning on critical thinking gains in science and mathematics courses at a research university in the Pacific Northwest. Results of this study showed that peer-led team learning has a small but positive impact on critical thinking gains in some science courses, and that it improved grade performance and retention in science and mathematics courses, particularly for females.

Berkant (2009) investigated the students’ meaningful causal thinking abilities in terms of academic achievement, reading comprehension and gender. The study documented significant relationships between meaningful causal thinking and academic achievement, and between meaningful causal thinking and reading comprehension. But no significant difference revealed between male and female students on the variables.

Quitadamo, Faiola, Johnson and Kurtz (2008) compared community-based inquiry method with traditional lecture method in general education Biology. Results showed significant critical-thinking gains in the community-based inquiry group but decreases in a traditional group and a mixed community-based inquiry/traditional group. Females, who showed decreased critical thinking in traditional courses relative to males, outperformed their male counterparts in community-based inquiry courses.

Mbano (2003) evaluated the effects of a Cognitive Acceleration intervention programme on the performance of secondary school pupils in Malawi by using quasi experimental design. The results showed that there was a significant difference between the experimental and control girls only in physical science. The experimental boys outperformed control boys in all the four subjects tested. These results indicated that the effects of Cognitive Acceleration Approach were more pronounced on boys than girls in Malawi.

Iqbal and Shayer (2000) investigated Pakistani secondary school students' development of formal thinking with an intervention programme, -
Science and Mathematics achievements improved at the end-of-year examinations. Males' cognitive development was better than that of the females in the public school.

Jennifer (1998) investigated the effect of Richard Paul’s model for critical thinking on student achievement in primary source document analysis and interpretation, argumentative reasoning, critical thinking dispositions, and history content in a community college history course. This study also examined whether age or gender moderated the effectiveness of the instructional method. Three major findings revealed that the students’ abilities to think historically and to think critically improved and that age and gender did not play significant roles in developing the college students’ critical thinking abilities.

**Overview of the studies related to gender influence**

The investigator identified two studies relating Cognitive Acceleration Approach and gender. Mbano (2003) evaluated the effects of a Cognitive Acceleration intervention programme and found that the effects were more pronounced on boys than girls in Malawi. Iqbal and Shayer’s (2000) study on Pakistani secondary school students' development of formal thinking with an intervention programme revealed that males' cognitive development was better than that of the females’.

The investigator reviewed a number of studies relating thinking skills and gender. Quitadamo, Brahler and Crouch (2009) examined the impact of peer-led team learning on critical thinking gains in science and mathematics courses and found that peer-led team learning has a small but positive impact on critical thinking gains in some science courses, and that it improved grade performance and retention in science and mathematics courses, particularly for females. Quitadamo et al. (2008) compared community-based inquiry method with traditional lecture method in general education Biology and found that Females, who showed decreased critical thinking in traditional courses relative to males, outperformed their male counterparts in community-based inquiry courses. Jennifer (1998) examined whether age or gender moderated the effectiveness of
the instructional method and found that gender did not play significant roles in developing the college students’ critical thinking abilities. Lee, Teo and Chai (2010) found no significant mean differences between the male and female pre-service teachers' knowledge and regulation of their own thinking. Sibichen (2009) found significant differences between the male and female teacher education students’ thinking skills. Berkant (2009) found no significant difference between male and female students on meaningful causal thinking abilities.

Hudson and Treagust (2013) found that male students outperformed female students in both the university entrance and school tests, particularly in the higher scores. Zeidan (2010) found that association between attitude toward biology and the biology learning environment were significant for girls. Desy, Peterson and Brockman (2011) found that Females reported more anxiety about science as well as less motivation in and enjoyment of science than males.

The investigator could not find a comprehensive study connecting gender and all dependent and independent variable though she made a thorough survey of the studies.

Conclusion

After reviewing the research studies related to different variables related to the present study, it can be concluded that most of the models and methods in classroom practices are effective in improving achievement in various subjects, thinking skills and attitude towards Science Learning. It is also evident from the studies that while comparing these models and methods with that of traditional method, the former is more effective.

The present study rests chiefly on the assumption that development of thinking skills of children is a pre-requisite for preparing them for their future life. It will give them the greatest control over their lives and learning. For this, they must be encouraged to think critically, creatively and imaginatively at the highest possible levels. If they are to become self-directed learners capable of learning by themselves, think flexibly and make reasoned judgements, then they must be taught explicitly how to do it.
Most of the reviewed studies on thinking skills revealed that the percentage of students’ attainment in thinking skills is at moderate level. So it is high time that we adopt innovative techniques which will make our students independent thinkers. The reviewed experimental studies on the dependent variables showed that diversity of teaching strategies is one of the most influential factors of student achievement and attitude towards Science. There are many research evidences for the significant improvements in cognitive development and science achievement through the application of Cognitive Acceleration Approach. Since the investigator could not find studies in this new approach in the Indian context it is clear that, research in this area is a requirement of the time.

All the surveyed studies related to the Cognitive Acceleration Approach (CAA) were either case studies or intervention programmes extended for one or more years in science and mathematics achievement, academic and cognitive development, cognitive and thinking skills, metacognitive development, problem solving in mathematics, social development, communication skills and social skills and the development of motivation. The investigator could not find any study which experiments the effect of Cognitive Acceleration Approach on, Thinking Skills in Chemistry, Attitude towards science learning and Achievement in Chemistry through the regular classroom teaching. The investigator could not find a comprehensive study connecting gender and all dependent and independent variable though she made a thorough survey of the studies. Moreover the investigator became curious to know whether the effectiveness of instruction based on CAA for a short term, viz., three months, will be having any effect on thinking skills. The fact that it was never investigated as a normal classroom teaching approach and the lack of studies on CAA in Indian context made the investigator fascinated to know whether the CAA is beneficial for classroom teaching if the treatment period is limited to a short period.

The methodology of the study is presented in the next chapter.