CHAPTER 2

REVIEW OF RELATED LITERATURE

Review of the related literature, an essential aspect of a research study, refers to a general retrospective survey of previous writings pertaining to one’s problem. Familiarity with the related literature develops an insight into the problem, helps the researcher to discover what is already known, what others have attempted to find out and what problems remain to be solved. It guards against the possible limitations and minimizes the chance of duplication or repetitions. Thus, it is essential for a researcher to know what sources are available, what sources to use, and where and how to find them thereby saving many hours of aimless activity.

The present chapter is devoted to the review of research studies that are thought to have some bearing on the problem selected by the researcher. In order to develop deep insight and to evaluate the methodological practices emerging, the researcher made a survey of the available literature and reviewed the research studies based on computer assisted instruction in Science education. A thorough and prudent study of various books, journals, research papers and educational reviews has resulted in the accumulation of certain amount of literature with respect to the topic under consideration. The researcher made an extensive search of all relevant studies in educational literature and selected those that were thought to be significantly related to the topic under investigation.

For the sake of convenience, the investigator has divided this chapter into the following sections:

2.1 Computer Assisted Instruction (CAI) in Science Education
2.2 Effects of Traditional Teaching and CAI on Attitude towards Physical Science
   2.2.1 Gender and Attitude towards Physical Science
2.3 Effects of Traditional Teaching and CAI on Achievement in Physical Science
   2.3.1 Gender and Achievement in Physical Science
2.4 Teacher-centered CAI Versus Student-centered CAI
2.5 Attitude towards CAI
2.6 CAI Learning Environment
2.7 Critical Appraisal of the Reviewed Literature
2.1 Computer Assisted Instruction (CAI) in Science Education

The spectrum of the types of approaches investigated in computer-based science learning has undergone steady change in the last so many years. During the last three decades, the largest proportion of research reports involved computer-assisted instruction (CAI) and its various modes (tutorials, drill & practice, simulations, instructional games and problem-solving). Many science educators have hoped that CAI and its modes would substantially help teachers provide students with efficient and effective opportunities to learn both science products - facts, principles, laws, and theories and its processes - manipulative and cognitive methods employed in the collection, analysis, synthesis, and evaluation of evidence. This is a review of the impact upon science learning of classroom and laboratory uses of CAI and its different modes as revealed by published research.

2.2 Effects of Traditional Teaching and CAI on Attitude towards Physical Science

Attitudes of students toward subjects in science are important because they influence students’ science achievement. Several studies reported the positive effects of CAI on attitude towards science. Geban, Askar, and Ozkan (1992) investigated the effects of the computer-simulated experiment (CSE) and the problem-solving approaches on 9th grade students’ attitudes toward Chemistry. Chemistry Attitude Scale was used to measure their attitudes. The results indicated that that the CSE approach produced significantly more positive attitudes toward Chemistry than the problem-solving approach and conventional approach, with the conventional approach being least effective. Yalcinalp, Geban, and Ozkan (1995) also examined the effect of a CAI tutorial, used as a problem-solving supplement to classroom instruction, on students’ attitudes toward Chemistry. The data were analyzed using two-way analysis of variance and t-test. It was found that the students who used the CAI accompanied with lectures scored significantly higher than those who attended recitation hours in terms of attitudes toward Chemistry. Similarly, Ozmen (2008) studied the effect of computer-assisted instruction on 11th grade students’ attitude towards Chemistry. The Chemistry Attitude Scale (CAS) consisting of 25 items was administered in the form of a pre-test and post-test. Analyses of scores of the experimental (n=25) and control (n=25) groups on the post-test showed a statistically
significant difference between groups in favour of the experimental group. Similar results were obtained by Akçay, Durmaz, Tüysüz, and Feyzioğlu (2006) and Akçay, Tüysüz, and Feyzioğlu (2003). Further, Chang (2002) compared the relative effectiveness of a problem solving-based computer-assisted instruction (PSCAI) and a lecture-Internet-discussion instruction (LIDI) for Taiwan senior high school students’ attitudes toward science measured by the Attitudes toward Earth Science Inventory. A multivariate analysis of covariance suggested that there were statistically significant differences in favour of the PSCAI on students’ attitudes toward the subject matter. Furthermore, Chang (2003) found that teacher-directed CAI (TDCAI) students in a secondary school in Taiwan had significantly higher score gains than student-controlled CAI (SCCAI) students as far as their attitude towards earth science course was concerned. In addition to this, Chang (2004), while exploring whether the effects of different forms of computer-assisted instruction (CAI) on student learning outcomes were influenced by student preferences of learning environment (PLE), concluded that teacher-centered CAI (TCCAI) group had significantly better attitudes toward earth science than did the student-centered CAI (SCCAI) group. Furthermore a significant PLE-treatment interaction was found on student attitudes toward the subject matter, where the teacher-centered instructional approach seemed to enhance more positive attitudes of students having less constructivist-oriented learning preferences; whereas the student-centered method was more beneficial to students having more constructivist-oriented learning preferences as far as their attitudes toward earth science in a computer-assisted learning environment was concerned.

Additionally, Zacharia (2003) studied the effect of using interactive computer-based simulations (ICBSs), laboratory inquiry-based experiments (LIBEs), and combinations of an ICBS and a LIBE, in a conceptually oriented physics course on science teachers’ beliefs about and attitudes toward the use of these learning and teaching tools, as well as the effect on their intentions to incorporate these tools in their own future teaching practices; science teachers’ attitudes toward physics and the effect that the use of ICBSs and/or LIBEs have on teachers’ attitudes toward physics, and whether teachers’ beliefs have an effect on their attitudes and whether their attitudes have an effect on their intentions. A pre–post comparison study and the Theory of Reasoned Action (TRA) were used for this purpose. Results confirmed the TRA model that beliefs affect attitudes and these attitudes then affect intentions, and
showed that science teachers’ attitudes toward physics, the use of an ICBS, the use of a LIBE, and the use of a combination of an ICBS and an LIBE were highly positive at the end of the study. Similar results were also reported by a few researchers (Harwood & McMahon, 1997; Hounshell & Hill, 1989). Similarly, in India, Phoolwala (1997) conducted a study to know the opinion of the students towards science teaching through microcomputer. The results revealed highly favourable opinion towards science teaching through microcomputers among the students of experimental group.

On the other hand, a study by Cavin, Cavin, and Lagowski (1981) showed that there was no significant difference between CAI and non-CAI with respect to chemistry attitudes. Similarly, Chang (2001), while comparing the effects of a Problem-Solving based Computer-Assisted Tutorial (PSCAT) and Lecture-Internet-Discussion (LID) teaching approach on attitude towards earth science of tenth graders (16-year olds) in a senior high school in Taiwan, concluded that none of the groups showed statistically significant increase or decrease in their attitudes. Similarly, Gönen, Kocakaya, and İnan (2006) found that the student’s attitudes towards Physics learning were not affected by different instruction methods.

2.2.1 Gender and Attitude towards Physical Science

Yalcinalp, Geban, and Ozkan (1995) found no significant difference between females and males from either experimental or control group in terms of their attitude towards chemistry, while studying the effect of a CAI tutorial, used as a problem-solving supplement to classroom instruction, on students’ understanding of chemical formulas and mole concept. Similar results were obtained by Akçay et al. (2003).

2.3 Effects of Traditional Teaching and CAI on Achievement in Physical Science

A number of researchers used a true experimental pre-posttest design to compare the effects of traditional teaching and CAI or its different modes on achievement in Physical Science (Akçay, Durmaz, Tüysüz, & Feyzioğlu, 2006; Bayrak, 2007; Gönen, Kocakaya, & İnan, 2006; Morgil, Oskay, Yavuz, & Arda, 2003; Morgil, Yavuz, Oskay, & Arda, 2005; Serin, 2011). Akçay et al. (2006), while
comparing the effects of computer-based learning and traditional method on students’ achievement in analytical chemistry, obtained positive results. In a similar study, Gönen, Kocakaya, and İnan (2006) compared the effects of Computer Assisted Teaching and the 7E model of the Constructivist learning methods on achievement of high school students in physics classes. A statistical analysis of achievement tests showed a significant difference between the students’ achievement at the knowledge and comprehension levels of cognitive domain. On the other hand, no difference was noted between their achievements at the application level of cognitive domain. Similarly, Serin (2011) investigated the effects of the computer-based instruction on the achievement of science and technology students. Data analysis through ANCOVA revealed that there was a statistically significant increase in the achievement of the experimental group. Likewise, Morgil et al. (2003) conducted a study to find out the effect of traditional learning method and computer supported method on learning level of the university students in redox subject in chemistry education. Results showed a difference of about 48% between pre- and post-tests in the control group (n = 42). But in the experiment group (n = 42), the increase in the success was more than the control group. In a similar study, Morgil et al. (2005) found a 52% improvement was observed in the post-instruction test results of the students of the experimental group whereas the control group only improved by 31%, while comparing the traditional and the computer-assisted teaching methods for teaching a fundamental topic within chemistry education, acids and bases. But, Bayrak (2007) found no significant difference between the effects of computer based learning and the laboratory based learning on students’ achievement regarding electric circuits.

A few studies employed a true experimental post-test only design to compare the effects of traditional teaching and CAI or its different modes on achievement in Physical Science (Choi & Gennaro, 1987; Geban, Askar, & Ozkan, 1992; Mahmood, 2004; Tabassum, 2004). Choi and Gennaro (1987) compared the effectiveness of microcomputer simulated experiments with that of parallel instruction involving hands-on laboratory experiences for teaching the concept of volume displacement to junior high school students. In addition, they compared the degree of retention, after 45 days, of both treatment groups. They found that computer simulated experiences were as effective as hands-on laboratory experiences. This study also showed that
there were no significant differences in the retention levels when the retention scores of the computer simulation groups were compared to those that had the hands-on laboratory experiences. Similarly, Geban, Askar, and Ozkan (1992) investigated the effects of the computer-simulated experiment (CSE) and the problem-solving approach on 9th grade students’ chemistry achievement and science process skills. For this purpose, two experimental groups, using the CSE approach (n = 60) and the problem-solving approach (n = 70) respectively, were compared with the control group (n = 70) using the conventional approach. The treatment for all groups was carried out over 9 weeks. The instruments used were Chemistry Achievement Test, Science Process Skill Test, and Logical Thinking Ability Test. The results indicated that the CSE approach and the problem-solving approach produced significantly greater achievement in chemistry and science process skills than the conventional approach did. However, no significant difference was found between the CSE and the problem-solving approaches. In another study, Mahmood (2004) developed an interactive CAI tutorial to examine its effects on class IX students’ achievement in general science as compared to traditional method of instruction. Twenty pairs of students, matched on intellectual capacity, were selected and assigned randomly to control and experimental groups. The result revealed that the experimental group outperformed the control group as far as their achievement at different levels of the cognitive domain (namely, knowledge, comprehension, and application) and in different content areas of science (Biology, Chemistry, and Physics) was concerned. But, Tabassum (2004) carried out a study to find out the relative effects of CAI as supplementing strategy and traditional method on class IX students’ achievement in science. The experimental (n = 20) and control (n = 20) groups were equated on the basis of their achievement scores in Biology in the previous semester. Analysis of data revealed that the experimental group performed significantly better than the control group.

Further, a large number of researchers employed a quasi-experimental pre-post test design to compare the effects of traditional teaching and CAI or its different modes on achievement in Physical Science. Some of them reported positive findings (Ardac & Akaygun, 2004; Chang, 2001a, 2001b; Ozmen, 2008). Ardac and Akaygun (2004) made use of the capabilities of computerized environments to enable simultaneous display of molecular representations that correspond to observations at
the macroscopic level. They addressed the immediate and long-term effects of using a multimedia instructional unit that integrates the macroscopic, symbolic, and molecular representations of chemical phenomena. Forty-nine eighth graders received either multimedia-based instruction that emphasized molecular representations (n = 16), or regular instruction (n = 33). Students who received multimedia-based instruction outperformed students from the regular instruction group in terms of the resulting test scores and the ease with which they could represent matter at the molecular level. However, results relating to the long-term effects suggested that the effectiveness of a multimedia-based environment can be improved if instruction includes additional prompting that requires students to attend to the correspondence between different representations of the same phenomena. But Chang (2001a, 2001b) investigated the effects of a Problem-Solving based CAI on students’ achievement. Chang (2001a) explored the effects of a Problem-Solving based Computer-Assisted Tutorial (PSCAT) on earth science achievement of tenth graders in a senior high school in Taiwan. The experimental groups (n = 72) received the PSCAT; whereas the comparison groups (n = 65) received a Lecture-Internet-Discussion (LID) teaching approach. A multivariate analysis of covariance on the post-test scores of the Earth Science Achievement Test, with students’ pre-test scores as the covariates, suggested that PSCAT produced (almost) significantly greater gains on students’ earth science achievement than did the LID approach. Along the same lines, Chang (2001b) also explored the effects of a Problem-Based Computer-Assisted Instruction (PBCAI) on students’ earth science achievement in Taiwan. During a 2-week period, the experimental group students (n = 84) received the PBCAI while the comparison group students (n = 75) received a Direct-Interactive Teaching Method (DITM) accompanying with regular computer-internet usage. An analysis of covariance on the Earth Science Achievement Test posttest scores with students’ IQ and pretest scores as the covariates suggested that the PBCAI was more effective in promoting students’ achievement than was the DITM, and that the students in the experimental group had significantly higher achievement scores than did students in the comparison group, especially on the knowledge and comprehension test items, but not on the application test items. Similarly, Ozmen (2008) studied the effect of computer-assisted instruction on 11 grade students’ achievement in Chemistry. The Chemical Bonding Achievement Test (CBAT) consisting of 15 two-tier questions was administered in
the form of a pre-test and post-test. Analyses of post-test scores by t-test showed that the students in the experimental group (n = 25) scored higher than the students in control group (n = 25) on the achievement test, indicating they had developed a better understanding of chemical bonding as a result of the CAI intervention.

Less conclusive findings on the effects of CAI on achievement were also reported by a few researchers who used a quasi-experimental pre-post test design (Chang, 2002; Pol, Harskamp, & Suhre, 2005). Chang (2002) compared the relative effectiveness of a problem solving-based computer-assisted instruction (PSCAI) and a lecture-Internet-discussion instruction (LIDI) for Taiwan senior high school students’ science achievement measured by the Earth Science Achievement Test. Experimental group students (n = 156) received the PSCAI; comparison group students (n = 138) received the LIDI. A multivariate analysis of covariance suggested that students taught using the PSCAI scored higher but not significantly higher than did students in the LIDI group. But Pol et al. (2005) developed a computer program about the subject of forces, containing hints for the various different episodes of problem-solving. A study was undertaken with a group taking part in the experiment (n = 11) who used both their textbook and the computer program, and a control group (n = 25) who used their textbook only. There was evidence to show that the pupils from the group taking part in the experiment did achieve higher results in solving problems. Exploration and planning were improved but evaluation was not. It appeared that pupils involved in the experiment made better use of their declarative knowledge in solving problems than pupils from the control group.

While employing a quasi-experimental post-test only design to compare the effects of traditional teaching and CAI on achievement in Physical Science, Dalgarno, Bishop, Adlong, and Bedgood (2009) compared the ability of a 3-dimensional Virtual Laboratory (VL) and a Real Laboratory (RL) to function as a tool for familiarizing students with the spatial structure of a laboratory and the apparatus and equipment it contains. After the VL-group (n = 11) had explored the simulation and the RL-group (n = 11) had been taken on a tour of the actual laboratory, all students were tested on their recall of the laboratory layout and their familiarity with apparatus. RL-group scored on average higher than VL-group. However, the difference was not significant at the 95% level in any of the tests. The researchers concluded that the Virtual
Laboratory is an effective tool for familiarization with the laboratory environment, especially for a student studying at a distance who does not have the opportunity to explore the laboratory.

Some studies did not mention clearly about the experimental design used but they reported important findings regarding the effects of CAI on achievement (Klahr, Triona, & Williams, 2007; Wu, Krajcik, & Soloway, 2001). Klahr, Triona, and Williams (2007) compared the effectiveness of using virtual and physical materials in a hands-on science, open-ended discovery, and design activity. Students (N = 56) were assigned to four different conditions, depending on whether they manipulated physical or virtual materials, and whether they had a fixed number of cars they could construct or a fixed amount of time in which to construct them. All four conditions were equally effective in producing significant gains in learners’ knowledge about causal factors, in their ability to design optimal cars, and in their confidence in their knowledge. While all students showed improvement on both the knowledge and performance assessments, there was no significant difference among groups on either measure. It was also found that students in the virtual materials group completed significantly more trials than those in the physical materials group, calling attention to other advantages for using the virtual materials, such as ease of development, duplication, and distribution of materials, as well as fewer time and space restrictions. On a similar note, Wu, Krajcik, and Soloway (2001) investigated how 11th grade students (N = 71) developed an understanding of chemical representations with the aid of a computer-based visualizing tool, eChem, that allowed them to build molecular models and view multiple representations simultaneously. The results of pre- and posttests showed that students understanding of chemical representations improved substantially. They concluded that a chemistry simulation’s visualization tools may have aided students in developing an understanding of chemical representations. Since student pairs used both physical model kits and simulations to build molecular models and compare micro- and macroscopic molecular representations, the researchers acknowledge that the simulation’s impact alone could not be extracted from that of the combination of instructional methods.

A number of researchers used a true experimental pre-post test design not only to study the effects of CAI and its different modes on achievement but also their role in helping students overcome their alternative conceptions or misconceptions in the
Baser (2006) investigated the effects of simulations based on conceptual change conditions (CCS) and traditional confirmatory simulations (TCS) on pre-service elementary school teachers’ understanding of direct current electric circuits. The data was collected from a sample consisting of 89 students; 48 students in the experimental group who were taught simulations based on CCS, and 41 students in control group who followed the TCS. Electric Circuits Concepts Test (DIRECT) was not only used as pre-test but also as post-test and delayed post-test. Science process skills and attitudes toward computers were taken as covariates. Analysis of covariance was used to analyze the post-test data collected after three weeks. The results showed that the conceptual change based simulations caused significantly better acquisition of conceptual change of direct current electricity concepts than the confirmatory simulation. Eleven weeks delayed post-test results showed that the experimental group outperformed the control group in understanding of direct current electric concepts. In another study, Weller (1995) reported on the investigation of a microcomputer-based system for the diagnosis and remediation of three Aristotelian alternative conceptions of force and motion held by eighth-grade Physical Science students. The two remediation simulations were designed to present scientific idealizations and to be perceived by the student as anomalous to the three alternative conceptions. Diagnosis and post-testing were done with computer-displayed, graphics-based, multiple-choice questions. Structured interviews were employed at several points during the study to obtain indications of the conceptions of force and motion of students. A student’s possession of alternative conceptions was unrelated to whether the student was a strong or weak learner of science. Students who were currently studying dynamics in their classes exhibited a very different pattern of non-scientific answers on the computer diagnostic test than did students who had completed that topic. The completed students who were selected for possession of alternative conceptions were facilitated by the computer simulations in altering their naive conceptions to a significant degree. In studying the differences between using so-called Real Experimentation (RE) and Virtual Experimentation (VE), Zacharia (2007) compared a control group only using RE with an experimental group using a combination of RE and VE. The results indicated that replacing RE with VE during a specific part of the experiment has a positive influence on students’
conceptual understanding of electrical circuits, as measured by conceptual tests. Likewise, Zacharia, Olympiou, and Papaevripidou (2008) showed that the use of the combination of PM and VM had a greater effect on undergraduate students’ conceptual understanding of temperature and changes in temperature than the use of PM alone.

A number of researchers, who used a quasi-experimental pre-post test design not only to study the effects of CAI and its different modes on achievement but also their role in helping students overcome their alternative conceptions/misconceptions in the field of Physical Science, obtained positive results (Ozmen, 2008, 2011; Ozmen, Demircioglu, & Demircioglu, 2009). Ozmen (2008) studied the effect of computer-assisted instruction on 11 grade students’ conceptual understanding of chemical bonding. The Chemical Bonding Achievement Test (CBAT) consisting of 15 two-tier questions was administered in the form of a pre-test and post-test. Analyses of scores of the experimental (n=25) and control (n=25) groups on the post-test showed a statistically significant difference between groups in favour of the experimental group. The results also indicated that the students from the experimental group were more successful than the control group students in remediation of alternative conceptions due to CAI intervention. Similarly, Ozmen (2011) studied the effect of animation enhanced conceptual change texts (CCT–CA) on grade 6 students’ understanding of the particulate nature of matter (PNM) and transformation during the phase changes. A quasi-experimental design and one control group (CG, N = 25) and one experimental group (EG, N = 26) were used. While the control group was subjected to traditional instruction, the experimental group received CCT–CA instruction. Two different tests, The Particulate Nature of Matter Concept Test (ParNoMaC) and The Transformation of Matter Statement Test (ToMaSaT), were administered as pretest, posttest and delayed test to collect data. Results indicated that the performance of EG students was higher than the CG ones in posttest and delayed test. And also, the EG students were better in remediating their alternative conceptions related to the particulate nature of matter and transformations during the phase changes. Likewise, Ozmen, Demircioglu, and Demircioglu (2009) also determined the effect of conceptual change texts accompanied with computer animations on 11th grade students’ understanding and alternative conceptions related to chemical bonding. One experimental group (EG; N = 28) and one comparison
group (CG; N = 30) were used in the study. While the comparison group was subjected to traditional instruction, the experimental group received conceptual change text accompanied with computer animations instruction. Chemical bonding achievement test was applied as pre-test, post-test and delayed test to collect data. The results of the study indicated that the performance of EG students was greater than the CG ones in post-test and delayed test. And also, the EG students were better in remediating their alternative conceptions related to chemical bonding.

Further, Trundle and Bell (2010) used a quasi-experimental pre-post test design to compare the effectiveness of three instructional approaches in achieving desired conceptual change among early childhood pre-service teachers (N = 157). Each of the three treatments employed inquiry-based instruction on moon phases using data collected from: (1) the planetarium software program, Starry Night™, (2) nature observations and Starry Night™, or (3) nature observations alone. Data sources included drawings, intensive interviews, and a lunar shapes card sort. The data sets were analyzed via a constant comparative method in order to produce profiles of each participant’s pre- and post-instruction conceptual understandings of moon phases. Non-parametric tests of significance revealed that pre- to post-instruction gains were significant for all three treatments across all targeted concepts. The Starry Night™-Only treatment demonstrated statistically greater gains for sequencing moon phases than the other two treatments. However, there were no significant differences among the three treatments in regard to participants’ abilities to draw scientific moon shapes or in their conceptions of the causes of moon phases. But in an earlier study conducted to describe the conceptual understandings of 50 early childhood (Pre-K-3) Pre-service teachers about standards-based lunar concepts before and after inquiry-based instruction utilizing educational technology, Bell and Trundle (2008) found that before instruction none of the participants understood the cause of moon phases, and none were able to draw both scientific moon shapes and sequences. After the instruction with technology integration, most participants (82%) held a scientific understanding of the cause of moon phases and were able to draw scientific shapes and sequences (80%).

Numerous studies investigated the effects of CAI and its different modes, used as a supplement or alternative to traditional teaching, on achievement in Physical Science. Some researchers, who used a true experimental pre-post test design,
reported positive effects (Stern, Barnea & Shauli, 2008; Yalcinalp, Geban, & Ozkan, 1995; Zacharia, 2007; Zacharia, Olympiou, & Papaevripidou, 2008). Stern, Barnea and Shauli (2008) evaluated the effect of a dynamic software simulation on the understanding of the kinetic molecular theory by 7th graders. Students in the control group (n = 62) studied a curricular unit that addressed the differences in arrangement and motion of molecules in the three phases of matter. The experimental group (n = 71) studied the same unit combined with a few computer lessons using a software simulation. The results indicated that the students in the experimental group scored significantly higher than those in the control group. Nonetheless, while both groups of students improved their understanding of the kinetic molecular theory, the overall achievements were very low. Likewise, Yalcinalp, Geban, and Ozkan (1995) examined the effect of a CAI tutorial, used as a problem-solving supplement to classroom instruction, on students’ understanding of chemical formulas and mole concept. The objective was to assess the effectiveness of CAI over recitation hours when both teaching methods were used as a supplement to the traditional Chemistry instruction. Two classes were randomly selected in a secondary school. Each teaching strategy was randomly assigned to one class. The experimental group received supplementary instruction delivered via CAI, while the control group received similar instruction through recitation hours. The data were analyzed using two-way analysis of variance and t-test. It was found that the students who used the CAI accompanied with lectures scored significantly higher, on a 45-item posttest at the knowledge, comprehension, and application levels, than those who attended recitation hours, in terms of school subject achievement in Chemistry. Along the same lines, Zacharia (2007) investigated the value of combining Real Experimentation (RE) with Virtual Experimentation (VE) with respect to changes in students’ conceptual understanding of electric circuits. Experimental group (n = 45) and a control group (n = 43) attended a one semester course in Physics for pre-service elementary school teachers. Participants in the control group used RE to conduct the study’s experiments, whereas, participants in the experimental group used both RE and VE. Results indicated that the combination of RE and VE enhanced students’ conceptual understanding more than the use of RE alone. A further analysis showed that differences between groups on that part of the curriculum in which the experimental group used VE and the control group RE, in favour of VE. In a similar fashion,
Zacharia, Olympiou, and Papaevripidou (2008) investigated the comparative value of experimenting with physical manipulatives (PM) in a sequential combination with virtual manipulatives (VM), with the use of PM preceding the use of VM, and of experimenting with PM alone, with respect to changes in students’ conceptual understanding in the domain of heat and temperature. Participants in the control group (n = 31) used PM to conduct the experiments, whereas, participants in the experimental group (n = 31) used first PM and then VM. VM differed from PM in that it could provide the possibility of faster manipulation, whereas, it retained any other features and interactions of the study’s subject domain identical to the PM condition. Results indicated that experimenting with the combination of PM and VM enhanced students’ conceptual understanding more than experimenting with PM alone.

Some researchers, who used a quasi-experimental pre-post test design to study the effects of CAI and its different modes as a supplement to traditional teaching, also reported positive effects (Baltzis & Koukias, 2009; Kara, 2008; Limniou, Papadopoulos, Giannakoudakis, Roberts, & Otto, 2007; Liu, 2006). Kara (2008) carried out a study to determine the retention effect of CAI on 7th grade students’ achievement for teaching the Physics topics. An achievement test, consisting of 25 items on Force and Pressure units, was used as a pre-test, post-test and retention test. Traditional instruction method was used for control group (n=85) while traditional instruction with teacher supervised CAI method was used for experimental group (n=47). Independent samples t-test results demonstrated a significantly meaningful difference between groups’ post test as well as retention test scores in favour of the experimental group. In a study by Baltzis and Koukias (2009), students (n = 280) taking a course on analog electronics were encouraged to complete a circuit simulation task individually prior to performing a laboratory experiment in pairs and their academic performance was compared with students (n = 238) working in a laboratory without simulation. This integration of simulations tools in teaching led to an overall improvement of academic performance. In the same manner, Limniou et al. (2007) integrated an interactive viscosity simulator into a pre-laboratory session in an attempt to improve training in a chemistry laboratory. The students of the experimental group (n = 44) participated in a pre-laboratory session with additional instruction, including the use of the simulation on personal computers and other
discussions. After the pre-labs, these students participated in the design of the experiments using the simulator as an educational tool, and then carried out the experiments; in addition, they processed their data on spreadsheets, and they pooled their results through a Local Area Network (LAN). The students of the control group (n = 44) performed the experiments following the traditional teaching procedure (recipe-labs), without attending the pre-lab session. Statistical analysis indicated the significant differences in content knowledge between the experimental and control groups, proving that a collaborative pre-lab simulation exercise can improve content knowledge. Similarly, Liu (2006) conducted a study to test a hypothesis that computer modeling enhanced hands-on chemistry laboratories are more effective than hands-on laboratories or computer modeling laboratories alone in facilitating high school students’ understanding of chemistry concepts. Thirty-three high school chemistry students from a private all-girl high school in northeastern United States were divided into two groups to participate. Each group completed a particular sequence of computer modeling and hands-on laboratories plus pre-test and post-tests of conceptual understanding of gas laws. Each group also completed a survey of conceptions of scientific models. Non-parametric tests showed that the combined computer modeling and hands-on laboratories were more effective than either computer simulations or hands-on laboratory alone in promoting students’ conceptual understanding of the gas law on the relationship between temperature and pressure.

Some researchers, who used a quasi-experimental post test only design to study the effects of CAI and its different modes as a supplement to traditional teaching, obtained mixed effects. Jimoyiannis and Komis (2001) compared two groups, control (n = 60) and experimental (n = 30) of 15-16 years old students to determine the role of computer simulations in the development of functional understanding of the concepts of velocity and acceleration in projectile motions. Both groups received traditional classroom instruction on these topics; the experimental group used computer simulations also. The results showed that students working with simulations exhibited significantly higher scores in the research tasks. In the same manner, Cracolice and Abraham (1996) carried out a study to investigate the effects of computer assisted instruction and semi-programmed instruction as replacements for traditional recitation and discussion, on students’ problem-solving performance in General Chemistry. ANCOVA, partialling out the effect of formal reasoning ability,
was used to analyze the experimental data. The results indicated that for simple exercises, all methods of teaching were equally effective, but for difficult exercises, the semi-programmed instruction was most effective. In contrast to these positive results, negative effects were obtained in a study by Wainwright (1989). He evaluated the attributes of a commercial microcomputer software package as a supplement to traditional instruction in general chemistry classes in a suburban public high school. During a unit of study of writing and naming formulas and balancing chemical equations, the experimental group received reinforcement via microcomputer while the control group used parallel worksheet exercises over a period of three weeks for concept reinforcement. Analysis of achievement scores indicated significantly higher scores among the students in the control group.

In India, a number of researchers studied the effects of CAI on students’ achievement in Physics, mainly at the secondary and senior secondary levels. For instance, Kadhiravan (1999) compared the three instructional strategies viz. Lecture Method (LM), Computer Assisted Instruction (CAI) as individualized strategy and Computer Assisted Instruction with peer interaction (CAIPI) in terms of their effectiveness in improving the performance in Physics among the higher secondary students with different levels of cognition, viz. knowledge, application and understanding. The author also developed a syllabus based computer software package for the selected units in Physics at higher secondary level to evaluate it from the technical and pedagogical points of view. The sample consisted of 105 students of standard XI. The results showed that among the instructional strategies, viz. LM, CAI and CAIPI, CAIPI was the most effective instructional strategy in terms of realizing the instructional objectives in physics at higher secondary stage. Among the three instructional strategies, CAIPI is the most effective one in terms of its effectiveness in realizing the instructional objectives in the context of content with low difficulty level.

A number of Indian researchers had developed a number of CAI packages to examine their effects on students’ achievement in Physics. For instance, Jeyamani (1991) developed a Computer Assisted Instruction (CAI) package to test its effectiveness for teaching Physics to class XI students. Results showed that the experimental group performed significantly better than the control group. Similarly,
Sindhi (1996) developed a multimedia package for the teaching of Physics in class X to study its effectiveness on achievement of students. Results showed that there was a significant difference between mean of pre-test and post-test scores of the experimental group. There was also a significant difference between the mean post-test scores of control group and experimental group, proving that the teaching through multimedia package was more effective in comparison to conventional method of instruction. Likewise, Dange and Wahb (2006) studied the effectiveness of teaching Physics to class IX through Computer Assisted Instruction package based on the topic ‘Universe’. Results indicated no significant difference between the mean gain scores of pre-test and post-test for the control group (n = 16). But a significant difference was found between the mean gain scores of pre-test and post-test for the experimental group (n = 16). There was also a significant difference between mean post-test scores of control and experimental groups. In a similar study, Dalwadi (2001) developed a CAI package in Science on the unit of ‘Light’ for standard IX to test its effectiveness in terms of achievement of students. Results proved that CAI was an effective individualized instructional technique for teaching science. Along the same lines, Patel (2008) developed a CAI package on two units of Physics for class XI, namely ‘motion in one dimension and two dimensions’ and ‘Laws of Motion’, to compare its effectiveness with conventional method of instruction in terms of achievement of students. The package was found significantly more effective as reflected by significantly higher achievement of the experimental group (n = 30) than the control group (n = 30).

A few Indian investigators had also evaluated the effects of CAI on students’ achievement in Chemistry. For instance, Phoolwala (1997) conducted a study to compare the effectiveness of teaching a unit of science, namely ‘Carbon Compounds’ through microcomputer and traditional method of teaching. Results indicated a significant difference between the mean scores of pre-test and post-test of experimental group, proving that students can learn effectively through microcomputers. There was also a significant difference between the mean post-test scores of control group and experimental group, indicating that students can learn science effectively through microcomputer than through traditional method. In a similar study, Vasanthi and Hema (2003) studied the effectiveness of teaching
Chemistry through CAI over the traditional teaching method. Results indicated a significant difference between the mean gain score of the control (n = 30) and experimental (n = 30) groups for all units. But no significant difference was found between the mean post-test scores of control and experimental groups administrated for all units. In another study, Khirwadkar (1998) developed a CAI package based on three chapters of Chemistry for class XI to study the effectiveness of the software package in terms of achievement of students. The results indicated that the package was effective in terms of student’s achievement, as shown by significantly higher achievement of the experimental group (n = 30) than the control group (n = 30). Similarly, Parmar (2013) conducted an experimental study to find out the effectiveness of Computer Aided Instructional Material (CAIM) on Chemistry for students of standard XI by taking 55 students as sample using single group pre-test and post-test. Results found CAIM to be effective for learning the concepts of chemistry.

2.3.1 Gender and Achievement in Physical Science

A number of researchers also explored the effect that CAI had on achievement in Physical Science based on gender. Some of them found the positive effects of CAI on male students. Abouserie, Moss, and Barasi (1992) studied the effect of CAL tutorials and gender on 143 first year medical students’ achievement in a Physiology course. There were 66 male and 77 female students in the sample. The results revealed that there was a significant difference between males and females in their achievement scores in favour of the male group. Similarly, Choi and Gennaro (1987), while comparing the effectiveness of microcomputer simulated experiments with that of parallel instruction involving hands-on laboratory experiences, also assessed the differential effect on students’ understanding of the volume displacement concept using sex of the students as another independent variable. The results showed that males, having had hands-on laboratory experiences, performed better on the posttest than females having had the hands-on laboratory experiences. There were no significant differences in performance when comparing males with females using the computer simulation in the learning of the displacement concept. However, an ANOVA of the retention test scores revealed that males in both treatment conditions retained knowledge of volume displacement better than females. But less conclusive
findings regarding the effect of CAI based on gender were obtained by Klahr, Triona, and Williams (2007). They compared the effectiveness of using virtual and physical materials in a hands-on science, open-ended discovery, and design activity. Students (N = 56) were assigned to four different conditions, depending on whether they manipulated physical or virtual materials, and whether they had a fixed number of cars they could construct or a fixed amount of time in which to construct them. Results indicated that the girls’ performance, knowledge, and effort were equal to boys’ in all conditions, depending on whether they manipulated physical or virtual materials, and whether they had a fixed number of cars they could construct or a fixed amount of time in which to construct them.

Further, a number of other researchers found no gender effect on achievement. Baser (2006), while examining the effects of simulations based on conceptual change conditions (CCS) and traditional confirmatory simulations (TCS) on pre-service elementary school teachers’ understanding of direct current electric circuits, found that gender and interaction between gender and treatment did not significantly contribute to students’ understanding of direct current electricity concepts. While studying the effects of integrating an interactive viscosity simulator into a pre-laboratory session in an attempt to improve training in a chemistry laboratory, Limniou et. al (2007) also found no significant difference between male and female students from either experimental or control group, as far as their performance on knowledge-based questions was concerned. Similarly, Stern, Barnea and Shauli (2008) did not find any statistically significant gender differences while exploring the effect of a dynamic software simulation on the understanding of the kinetic molecular theory by 7th graders. Likewise, Yalcinalp, Geban, and Ozkan (1995) found no significant difference between the performances of females versus males from either experimental or control group while studying the effect of a CAI tutorial, used as a problem-solving supplement to classroom instruction, on students’ understanding of chemical formulas and mole concept. In a similar study, Tabassum (2004) concluded that CAI method was equally effective for both male and female students. Similar results were obtained by Akçay et al. (2003). Similarly, in the Indian context, gender-wise comparison was found to be insignificant, indicating that CAI is equally effective in teaching male and female students (Jeyamani, 1991; Patel, 2008).
2.4 Teacher-centered CAI versus Student-centered CAI

The effectiveness of learning from CAI derives little from the medium that is used. Instead, the benefits appear to come from the instructional design method used to develop or implement the CAI (Clark, 1994). Consequently, it might be more appropriate to evaluate the relative effectiveness of different instructional strategies on students’ learning. While previous studies and meta-analyses have primarily focused on the comparative efficacy of computer assisted instruction (CAI) versus traditional instruction, there have been relatively fewer examples of research exploring how various teaching formats of CAI influence student science learning outcomes in the secondary classroom. Therefore, Chang (2002) undertook a study to explore the effects of teacher-centered versus student-centered multimedia CAI on the science achievement of tenth-grade students in Taiwan. A total of 244 high school students participated in this pre-test/post-test comparison group experiment. During a one-week period, one group of students (n = 123) were taught by a teacher-centered multimedia CAI scheme whereas the other group of students (n = 121) was subjected to student-centered multimedia CAI. An analysis of covariance on the Earth Science Achievement test post-test scores with students’ pre-test scores as the covariate revealed that the teacher-centered approach was more effective in promoting the students’ science achievement than was the student-centered method, especially on the knowledge and application levels of the cognitive domain. Similarly, Chang (2003) compared teacher-directed CAI (TDCAI) and student-controlled CAI (SCCAI) in a compulsory Earth Science course in a secondary school in Taiwan. The participants in the study were 232 tenth grade students belonging to six sections of about 40 students each and a total of 125 females and 107 males. Each of the six sections was randomly assigned to either the teacher-directed CAI groups (three sections with a total of 119 students including 65 females and 54 males) or student-controlled CAI groups (three sections with a total of 113 students including 60 females and 53 males). A pre-test post-test control group experimental design was adopted. Data collection instruments included the Earth Science Achievement Test and the Attitudes toward Earth Science Inventory. A multivariate analysis of covariance suggested that TDCAI students had significantly higher score gains than SCCAI students on the set of achievement.
In another study, Chang (2004) investigated the effects of a teacher-centered versus student-centered computer-assisted instruction (CAI) on 10th graders’ Earth Science student learning outcomes. This study also explored whether the effects of different forms of computer-assisted instruction (CAI) on student learning outcomes were influenced by student preferences of learning environment (PLE). A total of 347 10th-grade senior high school students participated in this non-equivalent control group quasi-experiment. During a one-week period, one group of students \((n = 216)\) were taught by a teacher-centered CAI (TCCAI) model whereas the other group of students \((n = 131)\) were subjected to a student-centered CAI (SCCAI) method. Results showed that no statistically significant difference on students’ Earth Science achievement was found for either group. Likewise, Wu and Huang (2007) investigated ninth graders’ achievement in teacher-centered (TC) and student-centered (SC) technology-enhanced classrooms. 54 students from two science classes in Taiwan participated in this study. Of the two science classes, one class was randomly assigned as the student-centered (SC) class \((n = 25)\) and the other, the teacher-centered (TC) class \((n = 29)\). An achievement was administered as the pretest, posttest, and delayed posttest to assess initial understanding, changes, and retention of conceptual understanding test about force and motion. The statistical results suggested four main findings. First, students’ conceptual understandings about force and motion were significantly improved in both classes. It appeared that neither one of the instructional approaches was better than another in terms of helping students learn the concepts. Second, compared to high- and medium-achieving groups, low achieving students benefited less from the student-centered instructional approach and might need more guidance from the teacher when engaging in technology-enhanced learning activities. Third, high-achieving students could gain substantial understanding in either one of the learning environment, whereas medium-achieving students seemed to improve more in the student-centered learning environment. The fourth finding was that the effects of instructional approach on different achieving groups did not last long. Akçay, Tüysüz, and Feyzioğlu (2003) used a computer aided learning method based on ‘mole concept’ and ‘Avogadro’s number’ to study its effect on primary science classroom students’ success in science. For this purpose two experimental groups were compared, with the control group using conventional learning approach. The experimental groups were taught using the teacher centered computer-aided
education and student centered computer-aided education, respectively. Positive results were obtained for their success in science. Similarly, in India, Siddiqui and Khatoon (2013) investigated the effects of traditional instruction, teacher-centered computer assisted instruction (CAI) and student-centered computer assisted instruction on secondary school students’ achievement in Physical Science. A total of 120 tenth-grade secondary school students participated in this randomized pretest-posttest control group experimental study. These students were randomly divided into three groups, namely, control group (n = 40), Teacher-centered CAI experimental group (n = 40) and Student-centered CAI experimental group (n = 40). During a period of 5 weeks, control group was taught by traditional instruction, whereas Teacher-centered CAI and Student-centered CAI experimental groups were subjected to teacher-centered CAI and student-centered CAI methods respectively. An analysis of covariance on the Physical Science Achievement Test post-test scores with students’ pre-test scores as the covariate showed that the teacher-centered CAI approach was more effective in enhancing the students’ achievement in Physical Science than traditional instruction and student-centered CAI method.

Computerized learning environments offer several possibilities that can be used to improve the teaching of content along with the process. Research indicates that students benefit from additional guidance, particularly when computer-based instruction requires active construction of knowledge. On one hand, Ardac and Sezen (2002) examined the relative effectiveness of guided versus unguided computer based instruction with respect to regular instruction in improving content knowledge and process skills among students with low and high chemistry achievement levels. The results indicated that the effectiveness of computer-based instruction increased when learning was supported by teacher-directed guidance. Computer-based instruction (with or without guidance) was observed to be more effective than regular instruction in improving process skills particularly for students with high chemistry achievement. However, although the students who received regular or guided computer-based instruction showed significant gains in content knowledge, students under unguided condition failed to construct the expected content knowledge. While on the other hand, Limniou, Papadopoulos, and Whitehead (2009) compared two different teaching approaches which supported a pre-laboratory session by using the same simulation program. The investigation was conducted in two countries (Greece and
The Greek students attended the course in a computer cluster, where the teacher and the students had a face-to-face communication, while the English students participated in the on-line WebCT course, where there was an on-line asynchronous discussion. A crucial point which emerged from this investigation was that the simulation program in the two different pre-laboratory training sessions gave the same learning outcome; however, the learning characteristics and the teacher’s effort were different. The teacher’s role was slight difference in the two teaching approaches. In the computer cluster, the teacher had a more active role guiding students to obtain the expected learning outcome through face-to-face discussion and interaction, whereas in the case of the virtual learning environment (WebCT), the teacher had a more of a facilitator role focused on posing questions to the students and collecting the resources promoting the independent learning.

2.5 Attitude towards CAI

Computer assisted instruction (CAI), which is becoming widely available as an instructional medium individualizes the teaching and learning process so that it is somewhat more effective than conventional instruction. Secondary school student attitudes towards computer assisted instruction, and their perceptions about the difference between regular classroom and computer assisted instruction, are extremely important in obtaining feedback about CAI. Attitude of students towards CAI is a key factor for the success of computers as an educational technology. Therefore, a number of researchers had studied the effects of using CAI on students' attitude towards using computer and CAI in teaching-learning process. Some of them reported positive effects (Abouserie, Moss, & Barasi, 1992; Akçay, Durmaz, Tüysüz, & Feyzioglu, 2006; Akçay, Tüysüz, & Feyzioglu, 2003; Aşkar, Yavuz, & Köksal, 1992; Baltzis & Koukias, 2009; Hartley & Treagust, 2006; Limniou, Papadopoulos, Giannakoudakis, Roberts, & Otto, 2007; Wu & Huang, 2007; Yalcinalp, Geban, & Ozkan, 1995).

Abouserie, Moss, and Barasi (1992) studied the effect of CAL tutorials on 143 first year medical students' attitudes toward using CAL in a Physiology course. A questionnaire was used for the evaluation of students' attitude toward CAL. The results revealed that students had positive attitudes toward CAL but they were not prepared to rely entirely on CAL and also, there was no significant relationship between students' attitudes toward CAL and their achievement in this course. In a
study by Baltzis and Koukias (2009), students completed a circuit simulation task individually prior to performing a laboratory experiment in pairs. This integration of simulations tools in teaching led to increased interest in the course. Results showed that their positive attitude towards the course were mainly due to the integration of simulations tools in teaching. Similar results were obtained by Akçay et al. (2003, 2006). Also, Limniou, Papadopoulos, Giannakoudakis, Roberts, and Otto (2007) found that the students of experimental group, who participated in a pre-laboratory session with additional instruction including the use of the simulation, valued the opportunity to question the teacher in the pre-laboratory session, and that they found this teaching procedure useful. As a result, they felt more confident when they entered a laboratory and they understood better the theory behind the experiment than the CG students. They also found useful the collaboration with their peers. Finally, they agreed with the idea to have similar simulation programs created about other chemistry phenomena and experiments. Further, Aşkar, Yavuz, and Köksal (1992) measured the attitudes towards computer assisted learning for a group of 137 fifth-graders enrolled in a computer assisted science instruction. Positive attitudes towards learning from computers were found.

Furthermore, Hartley and Treagust (2006) investigated the effects of introducing computers in the Physical Science classroom of grade 12 learners in a rural school in the Western Cape Province of South Africa and explored the perceptions held by these students given their limited exposure and experience of working with computers. The perceptions were collected by interviews conducted with both individual students and groups, and an instrument, called the Computer Assisted Learning Environment Questionnaire (CALEQ), that was specifically developed for the school’s context. The learners’ responses indicated that they considered the inclusion of computers as improving their learning, while clearly articulating the importance of including the computers for teaching and learning from earlier grades. A need for more computers to create opportunities to work individually was also strongly indicated. Likewise, Wu and Huang (2007) administered a self-report questionnaire on teacher-centered (TC) and student-centered (SC) technology-enhanced classes after they completed the instructional unit in order to measure emotional engagement that involves students’ emotions, anxiety, and interests to technology-based learning activities. Students in the SC class reported having higher
emotional engagement in a technology-based learning environment. The results of item analyses showed that students in the SC class reported having significantly lower anxiety level, higher confidence, and more positive attitude toward using computers for learning. It seems that choice and opportunities to use simulations and manipulate variables could have positive impact on students’ emotional engagement. Further, Yalcinalp, Geban, and Ozkan (1995) examined the effect of a CAI tutorial, used as a problem-solving supplement to classroom instruction, on students’ attitudes toward the use of CAI in a Chemistry course. The data were analyzed using two-way analysis of variance and t-test. It was found that there was a significant improvement in the attitudes of students in the experimental group toward computerized instruction in a Chemistry course. But, Morgil et al. (2003, 2005) found that the attitude towards computer did not influence the achievement scores of experimental group.

A number of researchers had reported inconclusive findings regarding the effects of CAI on students’ attitude towards CAI (Cracolice & Abraham, 1996; Dalgarno, Bishop, Adlong, & Bedgood, 2009; Erdogan, 2009). Cracolice and Abraham (1996) investigated the effects of computer assisted instruction and semi-programmed instruction as replacements for traditional recitation and discussion, on students’ attitudes toward instruction in General Chemistry. The results showed that the semi-programmed instruction group had the most positive attitude followed by the computer assisted instruction group and then, the traditional group. This was due to the interaction between students’ attitudes toward instruction and problem-solving performance in General Chemistry. Similarly, Erdogan (2009) compared the effects of paper-based and computer-based concept mappings on computer attitude of the eight grade secondary school students. The students were randomly allocated to three groups and were given instruction on computer hardware. The teaching methods used for each group were the conventional method, paper-based concept mapping and computer-based concept mapping. At the end of a 4-week instruction, posttests were administered to assess computer attitude of the students. The findings indicate that paper-based and computer-based concept mapping strategies produce better results than the conventional method. However, the effects of paper-based and computer-based concept mapping strategies were not significantly different. Further, Dalgarno et al. (2009) designed a study to assess the usefulness of the Virtual Laboratory as a preparatory tool for university chemistry students studying at a distance, in advance of
their residential school laboratory sessions, and to find out the degree to which preparation using the Virtual Laboratory would reduce the anxiety of students and increase their confidence as they approached the laboratory sessions, as well as the degree to which it would improve their efficiency in the laboratory. It was found that only a minority of the students (29%) chose to use the Virtual Laboratory, those who did in general found it useful, but they were not able to identify a clear effect on the confidence and anxiety of students. It appeared that the students’ lack of confidence with their ability to understand the chemistry concepts and with their ability to carry out the mathematical calculations involved in the laboratory experiments were more important problems for many students.

A large number of studies included reports of teacher and student perceptions of learning content knowledge with the aid of computer simulations. In all cases, results indicated that most participants believed the simulations contributed positively to students’ understandings (Eichinger, Nakhleh, & Auberry, 2000; Zacharia, 2003, 2005; Zacharia, Olympiou, & Papaevripidou, 2008). During focus group discussions conducted by Eichinger et al. (2000), students cited several perceived advantages of using computer lab modules integrated into their introductory non-majors biology course, including the flexibility of the program, the ability to cover more topics in a shorter time period, the ability to work at their own pace, and to quickly run and repeat experiments. Additionally, students consistently reported that the programs helped them to visualize and clarify the concepts involved in the experiments; no quantitative evidence was collected to show that the programs influenced their knowledge, however. Other responses indicated that prior familiarity with a topic was necessary to reap maximal benefit from the simulation. Zacharia has undertaken a series of investigations considering the combined use of traditional instructional tools and computer simulations (Zacharia, 2003, 2005; Zacharia et al., 2008). Each had involved pre- and in-service teachers enrolled in a semester-long conceptual-based physics course. Zacharia (2003) investigated the effect of using computer simulation lab activities, traditional lab activities, and a combination of the two on teachers’ beliefs and attitudes toward using these resources in their teaching. Prior to the course, participants had little to no experience with simulations and preferred traditional hands-on inquiry-based labs alone to simulations or a combination of interventions. However, after the course, the majority believed that the combination of
a simulation and hands-on inquiry-based lab had the most advantages to offer to teaching and learning. The authors concluded that the exposure to the combination of interventions in the methods course positively impacted participants’ beliefs, attitudes toward, and intentions to integrate computer simulations into their instruction. Subsequent studies supported the conclusion that a combination of approaches may be more valuable than physical manipulatives alone, both in promoting more sophisticated scientific explanations and reasoning about natural phenomena (Zacharia, 2005) and in promoting science content knowledge and conceptual understanding (Zacharia et al., 2008).

Bear (1984) considered the attributes of the courseware in the use of CAI as critical to its success. While many variables influence the success of CAI, it is safe to assume that the type of CAI used, as well as the subject matter of investigation, will affect the outcomes of the CAI research (Hodgson, 1995). In looking specifically at studies in which CAI has been used in chemistry education, some research showed that CAI served to enhance achievement (Geban, Askar, & Ozkan, 1992; Prey, 1996). The extent to which CAI could facilitate students’ development of higher-level thinking skills associated with scientific inquiry was investigated by Maor and Taylor (1995). In two classes, students’ interactions with a scientific database were closely monitored, and the mediating roles of the seven high school teachers’ epistemologies were examined. The results of their study indicated that although the use of the computers in inquiry-based science classrooms offered the potential to facilitate students’ higher-level learning, the teachers’ epistemologies continued to perform a central role in mediating the quality of student learning. The authors concluded that teachers who adopted constructivist pedagogies which promoted both the personal and social processes of knowledge construction were more likely to enable students to better exploit the potential of computerized data bases for developing the higher-level thinking skills associated with scientific inquiry.

In India, a few researchers had studied the students’ attitude and reactions towards CAI and their perceptions regarding various features of different CAI software. For instance, Khirwadkar (1998) concluded that a majority of experimental group students had positive attitude about various aspects of software package especially regarding presentation of content, logical sequencing and language used for
understanding the content. In another study, Dalwadi (2001) found students’ opinions toward the CAI to be favourable as far as the statements related to the interest, mode of presentation, content clarity and the questions asked in the CAI were concerned. Similarly, Patel (2008) and Parmar (2013) also reached to the same conclusion.

2.6 CAI Learning Environment

Since the mid 1980s, a number of studies have been conducted to study the CAI learning environment and its effects on attitude and achievement. Maor and Fraser (1993) examined the perceptions held by 120 students and seven teachers of the learning environment in their inquiry-based computer classrooms by administering the Computer Classroom Environment Inventory (CCEI). This inventory measured the classroom environment on five scales – Investigation, Open-Endedness, Organization, Material Environment, and Satisfaction – had six items in each scale, and the responses were on a five-point Likert scale: Never, Seldom, Sometimes, Often, and Very Often. Both student and instructor forms of the inventory were designed. Within the inquiry-based computer classroom, the authors found an increase in student-perceived investigation and open-endedness, indicating a supportive learning environment for the development of inquiry learning and also the promotion of higher-level thinking skills. Although teachers’ and students’ perceptions showed a similar trend, teachers’ perceptions were more positive than those of the students in terms of open-endedness, organization, and material environment. They also reported a change in the teacher’s role from lecturer and conclusion-drawer to initiator and facilitator while using the computer to teach science; similar findings were reported by Ryba and Anderson (1990). During the same period, Teh and Fraser (1993) studied the learning environment associated with the use of computer-assisted learning in school geography classes in Singapore. They developed and validated a new classroom environment instrument, namely, Geography Classroom Environment Inventory (GCEI) specifically for the unique setting of computer-assisted learning. The four scales in this instrument – Gender Equity, Investigation, Innovation, and Resource Adequacy – differentiated significantly between perceptions of students in different classrooms. Moreover, the use of CAI led to a high impact in terms of achievement, attitudes, and classroom environment. The authors concluded that there was considerable scope to make use of
GCEI for computer-assisted learning environments in replicating the evaluation study of innovations in CAI as well as their investigation into the effects of CAI learning environment on student learning outcomes. Aşkar, Yavuz, and Köksal (1992) measured the perceptions of the difference between the computer assisted instruction environment and conventional classroom for a group of 137 fifth-graders enrolled in a computer assisted science instruction. Perceptions of the students were in favour of the computer assisted instruction.

In a study of computer laboratory environments, Zandvliet and Fraser (1998) looked at three aspects, namely, the physical environment, the psychosocial environment, and the information technology environment. For the physical environment, they developed an instrument called the Computerized Classroom Ergonomic Inventory (CCEI), which had five physical variables which were grouped into the domains of workspace, computer, visual and spatial environments, together with a measure of overall air quality. The psychosocial environment was measured by using five scales of the What is Happening in This Class (WIHIC) questionnaire (Fraser, Fisher, & McRobbie, 1996). These are Student Cohesiveness, Involvement, Autonomy, Task Orientation, and Cooperation. The questionnaires were administered to 1404 secondary school students in 81 classes. The results showed that there were significant correlations between the visual environment and both student cohesiveness and task orientation. There were also correlations between all psychosocial environment variables and student satisfaction, with regression analysis showing 36% of the variance in satisfaction may be accounted for by task orientation and autonomy; a similar result was obtained by Khoo and Fraser (1997).

Results of studies conducted over the past 40 years have provided convincing evidence that the quality of the classroom environment in schools is a significant determinant of student learning (Fraser, 2007, 2012). That is, students learn better when they perceive their classroom environment as more positive. Many of these studies have controlled for background variables with students’ perceptions of the classroom environment accounting for appreciable amounts of variance in learning outcomes, often beyond that attributable to background student characteristics (Dorman & Fraser, 2009). Recent studies have substantiated this position. For example, Kerr, Fisher, Yaxley and Fraser (2006) established positive relationships
between classroom environment and attitudinal outcomes in Australian science classes. Associations with students’ cognitive and affective outcomes have been established, using the SLEI, for a sample of approximately 80 senior high-school chemistry classes in Australia (Fraser & McRobbie, 1995), and 1,592 grade 10 chemistry students in Singapore (Wong & Fraser, 1996).

Wong, Young and Fraser (1997) investigated associations between three student attitude measures and a modified version of the SLEI (Science Laboratory Environment Inventory) involving 1,592 grade 10 students in 56 chemistry classes in Singapore. In India, Koul and Fisher (2006) found positive associations between scales of the WIHIC questionnaire and students’ attitude towards science. Similarly, Telli, Cakiroglu and den Brok (2006) found positive associations between scales of the WIHIC and students’ attitude to biology in Turkish high schools. Telli, den Brok and Cakiroglu (2010) investigated the associations between teacher-student interpersonal behaviour and students’ attitudes to science using the QTI with an attitude questionnaire for a sample of 7,484 grade 9–11 students from 278 classes in 55 public schools in 13 major Turkish cities. Their results revealed that the influence dimension of the QTI was related to student enjoyment, whilst the proximity dimension was associated with attitudes to inquiry. A few researchers have also investigated the relationship between learning environment, attitudes and achievement in middle schooling science classes and found positive results (Wolf & Fraser, 2008).

2.7 Critical Appraisal of the Reviewed Literature

The investigations of CAI in science during the past three decades have moved the field steadily forward. The diversity of software represented by these studies, with various instructional strategies and objectives, makes it impossible for a comprehensive synthesis to be made of the studies’ instructional outcomes and research results. Research with CAI has examined science learning in a wide variety of content topics. Many other investigations achieved mixed results with short-term treatments, where it is likely that longer-term interventions would have yielded more positive results. The reviewed studies that compared the application of CAI with traditional instruction seem to indicate that traditional instruction can be successfully enhanced by using CAI. Within traditional education they can be a useful add-on, for example serving as a pre-laboratory exercise or visualization tool. In most cases, CAI
showed improved learning outcomes. With regard to the cognitive domain, use of CAI appears to facilitate students’ conceptual understanding. Studies that specifically focused on using computer simulations as pre-laboratory exercise tools conclude that they can effectively support familiarization with the laboratory, improve students’ cognitive focus, lead to better comprehension of the techniques and basic concepts used in laboratory work, and better understanding. Thus, the results of research on the enhancement of traditional instruction with CAI are promising. However, a word of caution is warranted, as short-term increased understanding does not necessarily lead to meaningful learning over the long term, and most studies in this category investigated only short-term results. In order to ensure that meaningful learning takes place, it is necessary to attune teaching strategies and the curriculum to the use of CAI and vice versa, as by focusing curriculum on the development of scientific reasoning skills.

A number of methodological concerns justify caution in interpreting and generalizing the findings of several studies. For example, pre-tests were included for some, but not all studies. Without pretests or random assignment, group equivalency is not confirmed, rendering treatment comparisons difficult to interpret. Sampling methods were not clearly mentioned in a few studies. Furthermore, several studies did not include a comparison or control group. In these cases, the question remains whether students would have learned as much without CAI, under traditional instruction. In those studies that employed a variety of instructional interventions, the contribution of CAI to student outcomes is uncertain without appropriate controls. Both the participants’ familiarity and comfort with computers may have influenced their results. Teacher preparedness is another concern. While a number of teachers involved were described as familiar with CAI and its modes, it is not clear how well they were prepared to use them to teach science concepts. Additionally, the teachers’ views of technology and preferred teaching styles may have influenced outcomes. Such teacher differences may be particularly significant in studies concerned with whole-class teaching approaches, considering that the teacher plays a dominant role in organizing and facilitating learning activities in this setting. In other cases, instruction was guided by the researchers rather than the teacher. Whether the same findings would have been found in a typical classroom setting is left to be determined.
Novelty effects are another concern, particularly in the earliest studies when computers were not as prevalent in science classrooms. In early studies, the traditional classroom instruction was not clearly described, making comparisons across studies problematic. A number of reviewers have also raised the question of whether equal effort was devoted to developing and implementing experimental and control activities, suggesting that greater efforts toward the CAI-based learning experiences may have resulted in superior instruction. Finally, numerous concerns arose with the instruments utilized in these studies. Information regarding instrument reliability and validity was omitted for several studies, calling into question the appropriateness of the measures and interpretations made.

The effect of CAI on attitudes toward Physical Science is not as well researched as the effect on achievement. However, it appears that the results reported by the reviewed studies are equally as varied. A number of research studies have shown that CAI promotes positive attitude towards Physical Science. Similarly, the findings, as reported by the studies reviewed in this chapter, concerning the impact of CAI upon achievement in Physical Science are extremely variable. There is a significant amount of research that suggests that CAI does lead to some degree of improvement in achievement. If, as other research investigations have shown, there is a correlation between positive attitudes toward CAI and attitude towards science; positive attitudes toward CAI and achievement in science; as well as between positive perceptions of CAI learning environment and attitude towards science; between positive perceptions of CAI learning environment and achievement in science, CAI may have an indirect effect on achievement by promoting positive attitudes. However, the research studies cited in this chapter do not provide conclusive evidence that CAI will always or will most often promote positive attitudes toward Physical Science or increase achievement in Physical Science. Thus, in order to clarify the mixed results reported on the effectiveness of CAI on students’ attitude towards and achievement in Physical Science, the limitations addressed in this review were taken care of in this study. Clear descriptions of the treatment conditions were given. Questions of teacher preparedness and CAI quality were addressed. To achieve this goal, a sample of appropriate size was selected and a variety of tools were developed, validated, and used to collect quantitative data.