CHAPTER III

REVIEW OF RELATED LITERATURE

3.1 ANDES INTELLIGENT TUTORING SYSTEM
3.2 PROBLEM SOLVING ABILITY
3.3 CRITICAL THINKING
3.4 ACHIEVEMENT IN PHYSICS
The review of related literature is an inevitable part of any research work because a researcher cannot proceed without a strong base. There may be other researches already done on problems closely related to the field. So it is wise to update the information about what has been done in the area of his/her choice.

According to Mouly (1963), “A thorough review of the related literature is an integral part of the conduct of research, helping the researcher in the classification of his/her problem and the avoidance of unnecessary duplication”.

According to Best (1977), “A familiarity with literature in any problem area helps the student to discover what is already known, what others have attempted to find out, what methods of attack have been promising or disappointing and what problems remain to be solved”.

The review of the related literature helps the researcher to analyse the previous works to identify the gap in the area of his/her work and thus contribute to the knowledge in the field. It throws light into the efforts taken by others in similar situation and the way they handled it. It gives the researcher basic idea regarding the available tools and techniques, various methods to conduct the research, sampling techniques, techniques to analyse the data etc.

Keeping in mind the advantages of the review of related literature, the researcher carefully analysed the dissertations, articles and studies from journals and periodicals and all the available materials from web and are summarized in the following pages. The investigator tried to highlight the topic, design of study, sample selected, tools used, statistical techniques used and the major findings in each review.

The present study intends to develop a Strategy based on Andes Intelligent Tutoring System for Enhancing Problem Solving Ability, Critical Thinking and Achievement in Physics of Students at Higher Secondary Level.
Therefore the investigator reviewed literature related to Andes Intelligent Tutoring System, Problem Solving Ability, Critical Thinking and Achievement in Physics and are presented under the following heads.

3.1 Andes Intelligent Tutoring System

3.2 Problem Solving ability

3.3 Critical thinking

3.4 Achievement in Physics

3.1 ANDES INTELLIGENT TUTORING SYSTEM

Van Lehn, et al. (2005) presented a paper that include a comprehensive description of Andes. This paper describes the Andes pedagogical principles and features in detail, the system design and implementation. It starts with the description of the functions and behavior of Andes. It gives the detailed description of preparation of the work bench, how to proceed in each step, how to receive hints and the role of feedback followed by the design and implementation of Andes.

Van Lehn et al. (2005) reported the five years of evaluation of Andes from 1999 to 2003. Here Andes was used as part of the normal Academy physics course. Students in all sections (experimental and control) used the same textbook and took the same final exam, but different homework problems were assigned. Control groups solved their homework problems by hand and in the other sections, students were encouraged to do their homework on Andes. Students in the Control sections did the same hour exams (at the end of each month) as students in the Andes section. The hour exams had approximately 4 problems to be solved in 1 hour. The final exams comprised approximately 50 multiple choice problems to be solved in 3 hours. On the final exam, students just entered the answer, while on the hour exams, students showed all their work to derive an answer. The summary of the Hour – Exam results of all the
Review of Related Literature

five years were compared using ‘t’ test and the result indicated that Andes students scored reliably higher than the control students. The 30% of the total score of each question was given for the diagrams, 20% for variable definition, 40% for equations and 10% for answers with proper units. The results of the final exam scores also revealed that Andes students performed better than the control group students.

Gertner and Van Lehn (2000) presented a paper that gives an overview of Andes, focusing on the overall architecture and the student’s experience using the system. They reported that Andes is an Intelligent Tutoring System for introductory college physics. The fundamental principles underlying the design of Andes are: (1) encourage the student to construct new knowledge by providing hints that require them to derive most of the solution on their own, (2) facilitate transfer from the system by making the interface as much like a piece of paper as possible, (3) give immediate feedback after each action to maximize the opportunities for learning and minimize the amount of time spent going down wrong paths, and (4) give the student flexibility in the order in which actions are performed, and allow them to skip steps when appropriate.

Schulze, et al. (2000), evaluated Andes at the United States Naval Academy. The study consisted of two groups, an Experimental group called Andes group (n= 173) who solved the homework problems with the help of Andes Physics Tutor and a Control group (n= 161) who solved the homework problems with the help of pencil and paper. Both the groups have a historical record of high achievement. Andes was distributed via the Internet with students in the Andes group being given the URL. Twenty to thirty problems were selected as homework problems that require hardcopy solutions. After each problem solving session students in the Experimental group uploaded their log files which can be identified only by their ‘call names’. Students were tested both before the instruction and afterward to measure the learning gains.
Both the Andes group and the control group were given written instructions prior to the post test regarding the mode of evaluation. 40% of the mark is allotted for correct application of principles, 30% for appropriate drawings, 20% for the correct definition of symbols, and 10% for the correct numerical answer. The overall result is that the Andes group performed statistically better than the control group. From the survey it was clear that the greatest advantage of Andes was that it forces the students to organize their thoughts and procedures and to improve their accuracy. Andes demands the drawings, definitions and expressions completely accurate. The disadvantage identified in the study was that the language used need to be simplified to make it more user friendly.

**Summary**

The investigator reviewed all the available literature related to Andes Intelligent Tutoring System and found that it is effective in enhancing Problem Solving Ability of Undergraduate students (Van Lehn et al., 2005 and Schulze et al., 2000).

### 3.2 PROBLEM SOLVING ABILITY

The investigator reviewed articles, theses and research papers based on Problem solving Ability and presented below only those that discussed the difficulties faced by students while solving problems in Physics, models and strategies that enhances Problem solving ability in Physics. The studies are presented in the chronological descending order.

Nikat (2018) conducted a study among Senior Secondary School Physics Students in Indonesia to evaluate their Problem Solving ability through MAUVE Strategy (Magnitude, Answer, Units, Variables and Equation) with the help of a rubric developed for the purpose. The principle of MAUVE strategy evaluation is that teachers and students have an advantage in evaluating the learning of physics. The study was a descriptive quantitative
research. The data were collected through test, observation and interview. The subjects were 30 students of Islamic Senior High School of Pujon selected using Purposive sampling. The result of this study is that MAUVE strategy facilitates teachers and students in evaluating problems on the physics material. Students can check their own answers independently, and can evaluate themselves about what deficiencies need to be improved in solving physics problems. For teachers, MAUVE is one of the easiest strategies to resolve problem-solving skills.

Reddy and Panacharoensawad (2017) conducted an empirical study to evaluate the students Problem Solving Skills in Physics and the factors that make the Problem Solving difficult. Data were collected from 303 High School students from Chittoor district in Andhra Pradesh using a questionnaire developed for the purpose. The collected data were analysed using percentage Analysis. The results revealed the difficulty in Problem Solving as the lack of ability in remembering equations in physics subject, lack of practice of Physics problems during the classes, Poor mathematical skills, lack of motivation and inexperience of the teacher, Poor comprehensive skills on definitions, laws, and basic principles of physics, lack of enough books or materials on problem-solving in physics etc.

Sutha & Vanitha (2017) conducted a study to find out whether there exists any significant relationship between Problem solving ability and Achievement in Physics among Higher secondary school students. The survey study was conducted among 326 Higher Secondary School Students of Coimbatore district selected using simple random sampling. The investigator used standardized tools for collecting data regarding Problem Solving Ability and Achievement in Physics. The obtained scores were then analyzed using Percentage Analysis, t-test, ANOVA and Pearson’s Product moment correlation. The results revealed that the level of Problem Solving Ability is low and that of achievement is moderate among Higher Secondary School
Students. There is no significant difference in the mean scores of problem solving ability and Achievement in Physics with respect to medium of instruction, gender, location of the school, educational qualification of father, educational qualification of mother, occupation of father and occupation of mother among Higher Secondary Students. Also, there is no significant relationship between Problem Solving Ability and Achievement in Physics among Higher Secondary School Students.

Sirait (2016) studied the effect of utilizing Multiple Representations (such as verbal, sketch or pictorial, motion diagrams, force diagrams, graphs, bar charts, mathematical equation, ray diagrams, field diagrams, circuit diagrams etc.) while learning Physics and solving Physics problem. The study was conducted on a sample of 73 Senior High School students in Pontianak district-West Kalimantan of which 37 belongs to the Experimental group and 36 belongs to the Control group. Both qualitative and quantitative research methods were applied to identify students’ representation, to analyze students’ score and to find out the effect of multiple representations. The effect of multiple representations was analysed using Experimental Method. The result revealed that students who employed more than one representation (motion diagram, force diagram etc) while solving the problem scored higher than students did not. Therefore Multiple representations is effective and can be used as an alternative instruction to teach physics as it is very useful for students to understand the concept and visualize the problem before going to mathematical equation.

Kaur (2015) conducted a study to find out the effect of Computer based Simulations on Achievement in Physics, Problem Solving Ability, and attitude towards Physics with different levels of Intelligence. To conduct the study, the investigator adopted 2x3 factorial design. The sample constituted 360 students from three Government Schools of Chandigarh. These students were randomly assigned to the Experimental and Control groups based on their level of intelligence. The Experimental group was exposed to Computer based
interactive instruction and the Control group was exposed to conventional instruction each of 45 minutes duration. Both the groups were tested before and after the treatment using the tests – Achievement test, Problem Solving Ability test and Attitude Scale. t-test and ANOVA were used to analyse the data. The results revealed that the Experimental group performed better than the control group on Achievement in Physics and Problem Solving Ability. Also students with high level of intelligence performed better than those with average and low level of Intelligence. Also the students’ yielded better attitude towards Physics when exposed to Computer based Interactive Simulations.

Olaniyana and Omosewo (2015) investigated the effect of Target-Task Problem Solving Model on Senior Secondary School Students’ Performance in Physics. The investigator selected pre test – post test non equivalent group design to conduct the study. The sample constitutes 120 Senior Secondary school Students purposively selected from two schools, 60 per school. Initially both the Experimental and Control groups were pre tested using a Performance Test on Current Electricity (PTCE) and then the Experimental group was taught using the Target-Task Problem-Solving Model while the Control group was taught using the Lecture method. After the intervention, they were post tested using the same Performance Test. The data collected were analysed using Mean, Standard Deviation and Analysis of Covariance (ANCOVA), and the hypotheses put forward tested at an alpha level of 0.05. The study revealed that the Target-Task Problem-Solving Model has a positive effect on the Experimental group when tested with PTCE. Also there exists significant difference in the performance of high – medium and low scoring students taught using Target Task Problem Solving model. The low scoring students performed better than high scoring students. The findings also showed significant difference in the performance based on Gender. The male students performed better than female students.

Dehipawala, Shekoyan and Yao (2014) conducted a study to find out the effect of pre-exposure to basic mathematical skills on problem solving
ability, learning attitudes and math anxieties in general physics classes. To conduct the study, the investigator selected two sections of the same physics course and they were taught by the same instructor. But students in one section were exposed to 10-15 minutes review on mathematics before regular physics lecture. The other group was given a full 50 minute physics lesson. Thus the first group got less time to learn Physics, but they got time to review essential mathematics. The second group learned the lesson without getting any review on mathematics. But they get enough time to discuss, listen and ask questions. Both groups were taught the same physics concepts each day. Both groups were assessed by the same quizzes, exams, and surveys. At the end of the semester, the problem solving skills of both groups were compared to check whether review of mathematics before a physics lesson help to improve their problem solving skills of students. The results of the study revealed that mathematics review at the beginning of the class helped students to improve their problem solving skills in Physics.

Zewdie (2014) made an investigation of students’ approaches to Problem Solving in Physics courses in Debre Markos College of Teacher Education. The sample constituted 22 second year physics regular students selected using purposive random sampling technique based on their mid-exam workout problem score. Data were collected using closed and open ended questionnaire from the sample, review of students mid-exam papers and focused group discussion with students and their physics instructors. Analysis used both qualitative and quantitative techniques. Data collected using closed ended questionnaire were analysed quantitatively and those using open ended questionnaire and focus group discussion were analysed qualitatively. The results of the study showed that students didn’t use scientific approach while solving problems in physics and concentrated on mere mathematical calculations. More than half of the students used Memory based approach (similar problems in the past) to solve Physics problems and others used plug and chug method. Conceptual understanding of the problem was found to be
low. Students were only interested in the final answer of the problem and never tried to interpret the meaning. The investigator recommended the Physics teachers to help their students concentrate on understanding of the problem before they rush to calculations and reporting and explain real situations.

Adolphus, Alamina and Aderonmu (2013) conducted a study to find out the Effect of Collaborative Learning on Problem Solving Ability in Physics among Senior Secondary School Students of Nigeria in Simple Harmonic Motion. The sample constituted 112 Physics teachers and 81 physics students from two urban and one rural school. The investigator conducted both survey and quasi experimental research to collect the data. The tools used for the study were Physics Teachers Questionnaire on Simple Harmonic Motion (PTQSHM) and Simple Harmonic Motion Achievement Test (SHMAT). Statistical data analysis tools utilized were the simple percentage, four point Likert-Scale of 2.50 criterion mark and t-test at 5% level of significance. The result of the findings showed that 1) mathematical calculations involved in SHM make students confident in the topic, 2) students were motivated when they co-operatively solve problems in Physics, 3) there was significant difference in the problem solving abilities among students taught using collaborative learning strategy and those taught with the conventional method. The study was in favour of Collaborative learning, 4) there is no significant difference between boys and girls in their problem solving abilities using the Collaborative strategy. Based on the findings, It was recommended that teachers should encourage group learning, group projects, tasks and assignments which facilitate collaborative learning and improves problem solving abilities among students.

Abubakar and Danjuma (2012) conducted a study to find out the Effect of Explicit Problem-Solving Strategy on students` Achievement and Retention in Senior Secondary School Physics. Solomon four group design was selected for the study, which involved 20 students in each group (80 in total) randomly
selected from SSII and assigned to the various groups in the design. The Physics Achievement test (PAT) developed by the investigator was used as the Pretest, Post-test and retention test. Both the experimental and control groups were pretested and then the experimental group were taught using the Explicit Problem Solving Strategy and the control group were taught using the lecture method. Then both the groups were post-tested. The retention test was administered to both the experimental and the control group with an interval of four weeks after the posttest. 3-Way Analysis of Variance was used for data analysis and the result revealed that Explicit Problem-Solving Strategy is better than lecture method in improving both Achievement and Retention in Senior Secondary School physics.

Gok (2012) conducted a real time assessment of problem Solving of Physics students using computer – based technology. The change in students problem solving ability was investigated through the application of a technological Interactive environment – Tablet PC Running Ink Survey by real time formative assessment as the class works through the problem solving strategies. Here students can write the equations in the Pc using a special pen. Here the instructor poses open format questions and student uses tablet PC to submit the responses. The instructor in back gives verbal guidance to the class as a whole. If the students mastered the content, then the instructor and students will move to the next. The study was conducted among a single selected group of 62 students of Advance Electricity and Magnetism course at University of Colorado. The method was evaluated by developed problem solving strategy survey as well as quizzes after each chapter of Electricity and magnetism. To analyze the data, the investigator used t-test. Results revealed that the developed interactive learning strategy increased the students’ ability to use problem solving strategies with even very difficult problems.

Hegde and Meera (2012) presented a paper based on the study on An Insight into the Learner's Approach to the Mechanism of Physics Problem Solving. The study composed of two phases. In the first phase, the investigator
analysed responses of large number of students (n=300) to selected Physics problems to identify the nature of the student difficulty in Problem Solving. This was then followed by an in-depth personal interview of smaller number of students, which is the second phase. A set of questions in the MCQ format, was designed for the first phase of the research. The students’ responses obtained during this first phase were analyzed. Based on these responses, relevant pointers pertaining to physics problem solving have been identified. The responses in the first phase acts as the input to the second phase, therefore no statistical analysis of the data of the first phase was carried out. In the second phase, to understand the underlying cognitive process of physics problem solving, the interview technique has been adopted. A major difficulty in problem solving was identified as the weak association of students’ conceptual framework to the physical principles. The physical terms in the problem statement act as trigger for the search of an equation and the inability to do so may hinder the problem solving completely. Also, the difficulty to proceed even when a student has access to the relevant equations is an exciting observation. The other weaknesses identified were the lack of mathematical manipulation skills and the difficulty students’ possess in connecting the symbols to the physical quantities. They always look at an equation in physics not as a relation between physical quantities but merely as a mathematical equation. An analysis of the results suggests the necessity of identification of the skill sets required for developing better problem solving abilities.

Serin (2011) conducted a study to find out the effect of Computer Based Instruction on Problem solving skills and Achievement of Science and Technology students. Pre – test, post – test non equivalent group design was selected for the study. A total of 52 students (26 in the Experimental group and 26 in the control group) participated in the study. To collect the data, the investigator prepared an Achievement test and a problem Solving Inventory. The experimental group received computer based science and Technology instruction for a period of three weeks and the Control group received normal
treatment. The data were analysed using t-test and ANCOVA. The result revealed that there is significant increase in the Achievement and problem solving skills of Students in the Experimental group that received the computer based science and technology instruction than those in the Control group.

Taale (2011) conducted an action research for Improving Physics Problem Solving skills of students of Somanya Senior Higher Secondary Technical School. The main objective of the study was to improve the problem solving skills of physics students and thereby increase their interest in physics and science to a great extent. To collect the data, the investigator prepared two tests containing three items each, which were similar in all aspects. One test is used as pre – test and the second test is used as post-test. The study was conducted on a sample of 16 students. A duration of four weeks’ intervention plan using an innovative method of teaching problem solving strategy was employed. The data collected using pre-test and post-test were analyzed using frequency counts and percentages. The post-test analysis showed that after the intervention there had been an improvement in the way students solve physics problems. The perception of the students that physics is too difficult appeared to have lessened. Students who once feared solving physics problems now ask for more exercises and assignments after the lesson has been taught.

Omiwale (2011) conducted a study to find out if there exist any significant Relationship between Problem-Solving Ability and Achievement in Physics among Senior Secondary School Students in Osun state, Nigeria .This study examined the problem-solving skills of students in relation to their Achievement in Physics. The investigator adopted Ex-post facto research design to conduct the study. A sample of three hundred and two (302) students was selected using stratified random sampling technique from a total population of 14,322 Senior Secondary School Students. Test of Problem-Solving ability in Physics (TPSAP) and Test of Achievement in Physics (TAP) with reliability indices of 0.78 and 0.87 respectively, were used for the study. The results of the study revealed that there exists significant relationship
between students’ Problem Solving Ability and Achievement in Physics for all students including male and female. Therefore it was concluded that Problem-Solving Ability is a critical variable of students’ Achievement in Physics.

Adeyemo (2010) conducted a study to find out Students’ Ability Level and their Competence in Problem-Solving Task in Physics. Survey method was adopted for the study. This study was carried out on 200 Senior Secondary School Physics students’ (100 males and 100 females) selected randomly from four Secondary Schools in Kosofe Local Government Area of Lagos State. The instruments used for the study were Achievement test in Physics and Students questionnaire. The data collected were analysed using simple regression analysis. The results of the findings showed that students’ ability and teaching-learning process have significant influence on problem-solving tasks. Also the problem solving task has a significant influence on the cognitive development of students.

Caliskan, Selcuk and Erol (2010) conducted a study to find out the effect of Instruction of problem solving strategies on Physics Achievement and self-efficacy beliefs. This study was conducted on two groups, Experimental (n=39) and control (n= 38) of student teachers in an introductory Physics course at University level. Pre test-post test non equivalent design was used. During the study, the experimental group received problem solving strategy instruction while the control group received traditional problem solving strategies. Both groups were pre-tested and post-tested using the tools - Physics Achievement Test (PAT) and Physics Self-Efficacy Scale (PSES). Repeated measures ANOVA was used to analyse the data. Results showed that the strategy instruction increased the performance of students in the Experimental group and has positive effects on Physics Achievement, and Physics Self-Efficacy beliefs. On the basis of the findings, it is strongly recommended that Physics instructors should use explicit problem solving strategy instruction in their lessons to develop students’ problem solving skills and related outcomes such as course achievement.
Ornek (2009) conducted a study to find out the effect of Physics modeling-based Interactive Engagement on Problem Solving Ability of students. The purpose of this study was to investigate how modeling-based instruction combined with an Interactive-Engagement teaching approach promotes students’ problem solving abilities. Physics modeling and Computer Simulations were used to satisfy the objectives thereby enhancing the conceptual understanding of Physical principles and Problem Solving ability of Students. The study was conducted among students who enrolled in the two – semester introductory Physics course at Purdue University. In this study, he examined students’ problem-solving ability during three physics problem-solving protocols phases. Interviews were conducted with students on an individual basis. The results showed that the modeling-based interactive teaching method may have an impact on promoting students’ physics problem solving ability and made them thinking like experts (physicists). It can be concluded that the modeling-based interactive teaching method may have the potential to promote students’ problem-solving ability in an introductory physics course.

Ogunleye (2009) conducted a study to find out Teachers' and Students' Perceptions of Problem-Solving Difficulties in Physics. This study investigated the aspects of students’ problem solving difficulties in physics and suggests possible remedies to overcome it. The investigator collected the data with the help of a questionnaire from 210 Senior Secondary School (SSS) physics students and 16 Physics teachers of Nigeria. The result of the analysis reveal that difficulty in understanding the problem, lack of enough practice in problem-solving in class and their poor mathematical skills constitute the major obstacles in solving physics problems. The study identified two major remedies that assist students in solving physics problems: they are 1) the provision of enough home assignments and 2) the employment of qualified physics teachers. It is recommended that students should be given opportunity
of having regular problem-solving sessions during the process of learning physics.

Pol., Harskamp., Suhre & Goedhart (2008) conducted a study on how Indirect Supportive Digital Help during and after solving Physics problems can improve Problem Solving Abilities. This study investigated the Effectiveness of computer – delivered hints in relation to problem solving abilities in two alternative indirect instruction schemes. In one instruction scheme hints are provided to students immediately after they are given a new problem to solve as well as after they have completed programme. In the other scheme hints are provided only after students have finished their solution. The hints are supplied using web – based program – Physhint. The experimental study was conducted in four schools comprised of three groups from each. Two groups received hints and the third group was the control selected for comparison. The results showed that both the computerized instructions were effective. Teaching students with the help of the program proved to be effective than with the text book. Also the instruction scheme in which hints are provided to students during problem solving proves to be more effective than the other who received hints after completing the problem.

Rodrigues and Oliveira (2008) studied the role of Critical thinking in Physics learning keeping in mind that critical thinking is essential for Science learning. The objective of the study is to find out whether there exist ant significant relationship between Critical Thinking of students with good performance in Physics and weak performance in Physics. The researcher selected Ex post facto research to conduct the study. The sample constituted 889 students of grade 9 belonging to 60 classes from 21 different schools. Cornell Critical thinking test was the tool selected for the study. The data were analysed using SPSS software. The results revealed that Critical Thinking is a predictor of the students’ performance in Physics. The critical thinking of students with good performance in Physics is higher than the Critical thinking of students with weak performance in Physics.
Valiotis (2008) conducted a study to improve Conceptual Understanding and Problem Solving Skills in Introductory Physics Courses using the Socratic Dialogue. Here the investigator explored the effect of Socratic Dialogue method -in conjunction with Interactive Engagement physics curricula- in improving student’s problem solving skills. The results showed that Interactive Engagement methods in learning help students develop higher cognitive functions, and arguably, will lead to transferable knowledge from physics to engineering. The study also revealed that problem solving ability can be further increased by using the Socratic Dialogue questioning method.

Bascones, Venezuela And Novak (2007) conducted a study to find out the effect of Alternative instructional systems based on Ausubel’s theory on the development of problem-solving skills in physics. Two different instructional approaches were used in a ninth grade Venezuelan Secondary School. One was the traditional approach which has been used for the last 10 years in Venezuela and the other was based on the learning theory of Ausubel (1968). The influence of these two different systems upon student-problem solving abilities was analysed using one-way ANOVA. The research findings suggest that instruction based on Ausubel’s theory was better able to develop problem-solving abilities, as measured by the acquisition of cognitive skills related to problem solving.

Praveen (2006) conducted a study to find out the effect of Mastery Learning Strategy on the problem solving ability in Physics of Secondary School Students. Here the effect was compared with the Conventional method of teaching. The investigator conducted an experimental study on a sample of 74 Secondary School Students from two divisions of Feroke Government Vocational Higher Secondary School. The design selected was pre – test, post – test non-equivalent group design. The investigator administered the problem solving ability test and achievement test (both prepared and standardized by the investigator) before and after the treatment. The obtained results were then analyzed using ‘t’ test, ANOVA and ANCOVA. The results revealed that there
is no significant effect of Mastery Learning Strategy on Problem Solving Ability in Physics of Secondary School Students.

Maurice (2005) assessed the effect of reasoning and hemisphericity on problem solving ability of learners. Reasoning and gender are found to be the most significant predictor of problem solving ability in science. It is also found that significant relationships exist between problem solving ability and reasoning ability in science. No significant difference in problem solving ability is found between students with right and left brain hemisphericity.

Leigh (2004) conducted a study on developing multi-representational problem solving skills in large, mixed-ability physics classes. Here the investigator used a new, research-based teaching strategy for the first year physics course in which multi-representational problem solving approaches were explicitly developed in order to provide an underlying foundation for the physics. The sample comprised of all Physics 1 students enrolled in 2002 and 2003 at the Cape Technikon. The teaching instruction based on the new strategy for physics problem solving was conducted for 15 weeks. A physics expectations survey was conducted both prior to and following the semester physics course. The overall impact of the new teaching intervention was assessed using course evaluation surveys and the results of the final three-hour Physics examination. It was found that more students were able to make appropriate use of the mathematical formulae needed to solve a physics problem after progressing through a series of non-mathematical representations of the particular problem situation. It was found that, as students’ confidence improved, so too did their attitudes towards the subject.

Foster (2000) conducted a study on the development of students’ problem-solving skill from instruction emphasizing qualitative problem-solving. This study examined the development of the problem solving ability of students in two college introductory physics courses where an explicit problem-solving strategy used in one class and no additional attempt was made to teach problem solving in the other class. The primary data used was the student's
solutions to exam problems which provide valuable insights into the students understanding of physics. These solutions were analyzed using a coding rubric developed based on the extensive research literature on problem solving. The coding rubric examined four skills - General Approach, Specific Application of the Physics, Logical Progression, and Appropriate Mathematics. The development of the students' problem solving skills was examined from the rubric. Results showed that the students in the course who were taught an explicit problem-solving strategy tended to develop their skills faster, but did not score any higher than the students in the more traditionally taught course by the end of the year. However, the students in the explicit problem-solving course consistently performed better on the multiple choice concept tests given during the year.

**Summary**

The investigator thoroughly analysed the available literature including studies and articles related to the variable Problem Solving Ability. The investigator identified the following difficulties in problem solving in Physics such as the lack of ability in remembering equations in physics subject (Reddy and Panacharoenasawad, 2017), lack of practice of Physics problems during the classes(Reedy and Panacharoenasawad,2017 and Ogunleye, 2009), Poor mathematical skills (Reddy and Panacharoenasawad, 2017, Hegde and Meera, 2012, Ogunleye, 2009) , lack of motivation and inexperience of the teacher(Reedy and Panacharoenasawad, 2017), Poor comprehensive skills on definitions, laws, and basic principles of physics (Reddy and Panacharoenasawad, 2017), lack of enough books or materials on problem-solving in physics(Reedy and Panacharoenasawad, 2017) , the weak association of students’ conceptual framework to the physical principles (Hegde and Meera, 2012), the difficulty students’ possess in connecting the symbols to the physical quantities (Hegde and Meera, 2012) , difficulty in understanding the problem (Ogunleye, 2009)etc. Also certain remedies that assist students in
solving physics problems were identified such as 1) the provision of enough home assignments and 2) the employment of qualified physics teachers (Ogunleye, 2009), Multi representational problem solving approaches Leigh (2004), providing hints during Problem Solving (Pol, Harskamp, Suhre & Goedhart, 2008) and mathematics review at the beginning of the class (Dehipawala, Shekoyan and Yao, 2014). Taale (2011) and Caliskan,,Selcuk and Erol ( 2010) developed innovative teaching strategies which lessened the difficulty in learning Physics. Kaur (2015) and Adeyemo (2010) identified that intelligence and ability level of students influences problem solving ability.

There exists some controversy regarding the relationship between Problem Solving Ability and Achievement in Physics. Omiwale (2011) identified significant relationship between these two variables but the findings of Sutha & Vanitha (2017) was against it.

Controversy also exists in the gender difference of Problem Solving Ability. Sutha & Vanitha (2017), Adolphus, Alamina and Aderonmu (2013) identified no gender difference in the Problem solving ability of Students but Olaniyana and Omosewo (2015) identified that male students performed better than female students in Problem Solving.

To Foster (2000), Explicit problem solving strategy has no effect on Problem solving ability of students but Caliskan, Selcuk and Erol (2010) found that the strategy is effective. The investigator identified certain strategies and techniques that enhances problem solving ability .They are MAUVE Strategy (Nikat, 2018), Multiple Representation (Sirait, 2016), Computer based Simulations (Kaur, 2015), Target-Task Problem Solving Model (Olaniyana and Omosewo, 2015), Collaborative Learning (Adolphus, Alamina and Aderonmu, 2013), Computer Based Instruction (Serin, 2011), Physics modeling and Computer Simulations (Ornek, 2009), Computer delivered Hints (Pol, Harskamp, Suhre & Goedhart, 2008), Socratic Dialogue Questioning method
(Valiotis, 2008) and Instruction based on Ausubel's theory (Bascones, Venezuela And Novak, 2007).

3.3 CRITICAL THINKING

The investigator reviewed so many articles, theses and research papers based on Critical Thinking and presented below only those that discussed the importance of Critical thinking in Science Education (general), Physics (in particular) and Mathematics (as problem solving is an essential part in Physics). The studies are presented in the chronological descending order.

Nisa, Koestiari, Habibbulloh and Jatmiko (2018) conducted a study to find out the Effectiveness of Guided Inquiry learning model to improve Critical Thinking of Senior High School Students of Indonesia. One group pre test and post test design was selected for the study. 90 students of grade X were the sample selected for the study. Critical Thinking test prepared by the researcher based on the topic Static fluid was given as pre test and post test. The collected data were analysed using t – test, N gain and ANOVA. From the results it is clear that the average score of critical thinking of students after the learning increased significantly. Therefore it can be concluded that learning static fluid with guided inquiry model is effective in enhancing Critical Thinking of students.

Mundilarto and Ismoyo (2017) conducted a research to find out the effect of Problem Based Learning on physics Achievement and Critical Thinking of Senior High School Students in Indonesia. The investigator selected pre-test, Post – test non equivalent group design to conduct the study and a total sample of 64 students (32 each in the Experimental and Control group) were selected. The Achievement test and the Critical thinking test developed by the investigator were used to collect data. Both these tests were administered before and after the treatment. During the treatment, the experimental group received classed based on Problem based learning and the
Control group received classes based on Demonstration method. The collected data were analysed using MANOVA at 0.05 level of significance. The results revealed the positive effect of PBL learning on Physics Achievement and critical Thinking of Senior High School Students.

Santos (2017) conducted a review to study the role of critical Thinking in Science Education. Through this review he explained the importance of Critical thinking in Science Education, the role of CT in Science Education, the ways to foster Critical thinking through Science Education, the current status of CT in Science education etc. The findings revealed the strong relationship between Critical thinking and Science Education. The investigator also identified some problems to implement CT in classrooms like the difficulty to apply the techniques to teach the subject. He identified various strategies that will enhance the CT skills through Science Education of which the most powerful one is the questioning technique.

Wartono, Hudha and Batlolona (2017) conducted a quasi-experimental research which aimed to determine the difference in Critical Thinking skills of the science students of standard X of who learned by using Inquiry-discovery model and Conventional learning model. The study was conducted on a total sample of 67 students of Malang, Indonesia of which 33 belong to the Experimental group and 33 belongs to the Control group. During the treatment the Experimental group learned the topic Static fluid by inquiry-discovery model and control group (n=33) by conventional learning model. The treatment was for two hours per week for all students. The Critical thinking test developed by the investigator was based on 5 indicators of critical thinking skills, namely the smoothness in giving simple explanation (elementary clarification), developing basic skills (basic support), drawing conclusion (inference), giving further explanation (advanced clarification), and setting strategies and tactics (strategies and tactics) (Ennis, 1993). The critical thinking was administered before and after the treatment to find out the
effectiveness of the teaching methods. The data were analyzed by using independent sample t-test. The results of the research showed that there was a significant difference in the Critical Thinking skills between the experimental and the control group. The critical thinking skills of the students taught by using *inquiry - discovery* model are higher than those of the students taught by using conventional learning.

Arulselvi (2016) conducted a study to find out whether there exists any significant relationship between Critical Thinking And Achievement in Physics of Higher Secondary school Students. Survey method was used to collect the data from a sample of 300 higher secondary school students selected using stratified sampling technique from Villupuram District of Tamil Nadu. Murthy critical thinking scale (2015) was used to collect the data. The data were analyzed using ‘t’ test, ANOVA and Pearson’s product moment co-efficient of correlation. The result showed that there was a significant positive relationship between critical thinking and achievement in physics, which confirms that critical thinking skills would help in learning physics. Also the study revealed that there exist no significant difference among higher secondary students in their critical thinking skills based on gender and type of management of schools. Also no gender difference was observed in the achievement test scores but observed 1% significant difference between higher secondary students in Achievement with respect to type of school which reveals that schools play an important role in increasing achievement among students.

Duran (2016) conducted a study to find out the effect of Inquiry based learning approach on Critical thinking skills of students in Science and Technology courses of Secondary classes. Pre-test, post-test control group design was selected to conduct the study. A total of 90 students took part in the study. Critical thinking skills scale developed by Demir (2016) was used to measure the CT of students. It was administered as pre-test and post-test. During the treatment the Experimental group received classes based on Inquiry
learning approach and control group using traditional method. The obtained scores were analyse using t-test and ANCOVA. The results revealed that Science and technology learning via Inquiry learning approach had significant effect on students Critical Thinking skills than traditional method.

Sherafat (2016) conducted a research to find out the effect of Critical Thinking, Study habits, and Self esteem on academic achievement of secondary and senior secondary school students of Mysore city. The investigator adopted descriptive research to conduct the study. The study was conducted on a sample of 625 students of 14 – 18 years of age. The researcher used Mysore Critical thinking Scale (MCTS) (developed by C.G Venkatesha Murthy, 2014), test of Study habits and attitude, and self esteem inventory to collect the data. The collected data were analysed using descriptive and Inferential statistics. The results revealed a high positive correlation between Critical thinking and academic achievement of students (secondary and senior secondary). But Study Habits and Self Esteem did not affect academic achievement of secondary school students.

Tiruneh, Cock, Weldeslassie, and Janssen (2016) developed and validated a Critical Thinking Test in Electricity and Magnetism (CTEM). This test was intended to measure students Critical Thinking skills in specific science domain such as Physics. This test was developed based on the components of Halpern’s critical Thinking Assessment (HCTA) - reasoning, hypothesis testing, argument analysis, likelihood and uncertainty analysis, and decision-making and problem-solving. The finalised test after item analysis contained 20 questions of which 18 items were constructed – response type and 2 were forced choice type items. The revised version of the test was then administered to 45 second year graduate students who enrolled in the E&M course six months prior to the test administration. To ensure the validity of the prepared tests, the HCTA test was administered immediately after the administration of CTEM test. The results revealed that the internal consistency
(Cronbach’s alpha=0.72) and inter-rater reliability (Cohen’s kappa = 0.83) of the CTEM test are acceptable. The findings suggests that the CTEM test can be used to measure the domain-specific CT skills in E&M, and a good basis for future empirical research that focuses on the integration of CT skills within specific subject matter instruction.

Kalelioglu and Gulbahar (2014) conducted a study to find out the effect of certain instructional techniques on critical thinking and critical thinking dispositions in online discussion based on triangulation design in which researchers implement the quantitative and qualitative methods during the same timeframe and with equal weight. The quantitative part was conducted using pre-test/post-test non equivalent group design. Six thinking hats, Brainstorming, Role Playing, Socratic seminar, and Anyone here an expert were selected as the instructional techniques for online discussion. The scores of the critical thinking dispositions were gathered through California Critical Thinking Disposition Inventory (CCTDI). In the qualitative part of the research, after the four-week experimental process, the messages in online discussion were analysed and digitised based on the content analysis model of critical thinking. The study was conducted on a sample of 24 pre-service teachers who were attending a compulsory undergraduate course offered by Computer Education and Instructional Technology (CEIT) at a private university in Turkey. Participants were randomly assigned to one of six groups by trying to equate academic achievement levels of group members. Each group composed of 4 students and there were a total of six groups formed for this study. In the quantitative part according to the results of ANOVA, except Socratic Seminar, there is no difference between groups in terms of scores of pretests and posttests on critical thinking dispositions. In the qualitative part according to the results of the analysis of critical thinking in online discussion, the Mixed techniques group performed as having the best ability of critical thinking, the Anyone expert group was second and the Brainstorming group was third in terms of performing critical thinking ability in online discussion.
Kumar (2014) conducted a study to find out the effect of Co-operative learning on Critical Thinking, Social Competency and Achievement in Social Science of Secondary School Students. The design selected was pre-test, post-test non equivalent group design. Two intact classes were selected for the study. One class was randomly selected as the experimental group (N= 57) and the other as the control group (N =59). Initially, Critical Thinking Skill Test, Critical Thinking in Everyday Life, Social Competency Scale and Achievement Test in Social Science were administered as pre-test to both the groups. Then the experimental group was taught through Jigsaw method (with modules prepared by the investigator). The duration was 60 minutes per day for 40 days. On the other hand, control group was taught by using conventional method. The duration and time period was kept same. Then the same tests were administered as post-tests. The findings revealed that Critical thinking skills of students taught using Jigsaw method of cooperative learning was significantly better than students taught using traditional method of teaching. Gender differences were not found in Critical thinking skill of students taught by Jigsaw method of cooperative learning and students taught with traditional method of teaching. The dimensions of CT such as Analogy, Interpretation and Inference of students taught by Jigsaw method of cooperative learning was significantly better than students taught with traditional method of teaching. But Evaluating Arguments, Logical analysis, Recognition of assumptions and deduction of students taught by Jigsaw method of cooperative learning and traditional method of teaching do not differ. Gender differences were found in Evaluating Arguments of students taught by Jigsaw method of cooperative learning and students taught with traditional method of teaching and the result was in favour of girls. But no gender difference was seen in the other dimensions like logical analysis, Recognition of assumptions and deduction.

Alijaafreh (2013) conducted a study on The Effect of using the Directed Inquiry Strategy on the development of Critical Thinking Skills and Achievement in Physics of Tenth Grade students in Southern Mazar. To
achieve the objectives of the study a teaching program using the directed inquiry strategy, an achievement test and a test of critical thinking were built. The sample consisted of 52 students that was intentionally selected and was divided into two groups. A control group of (27) that was taught using the traditional way and an experimental group of (25) students that was taught using the directed inquiry strategy. The results of the study showed that there was an effect of using directed inquiry strategy on the achievement and the development of critical thinking among tenth grade students in Southern Mazar educational directorate.

Amin (2013) conducted a study to find out whether the use of Portfolio based Physics learning model improve Critical Thinking skills of Students. The study was conducted on SMA students of 2010 –’11. The tools used were Critical Thinking test, questionnaire and observation sheet for teachers and students. Both qualitative and quantitative methods of research were adopted. Students in the experimental group learned through Portfolio based Physics learning model and students in the control group through conventional method. The data were analysed using N-gain. The results revealed the better performance of students in the experimental group than the control group. The Critical thinking of Experimental group is higher than the control group. Also the attitude of teachers and students toward the Portfolio based model was positive.

Kim, Sharma, Land and Furlong (2013) investigated the effect of incorporating Active Learning Strategies for enhancing Critical Thinking in a large undergraduate, general science education class. The three active learning strategies proposed were small-group learning with authentic tasks, individual writing and scaffolding. The study was conducted among 155 undergraduate students from an introductory geosciences course. Results indicate that the Active Learning Strategies had a positive significant effect on undergraduate students’ learning of geoscience concepts and the students’ Critical Thinking
displayed in written reports, suggests that the use of Active Learning Strategies in a large class were useful to enhance students’ critical thinking. Also by conducting survey and interview they found that the active learning strategies enhanced students’ engagement in various facets of critical thinking that are required in the geosciences field to solve real life problems. Students also reported that the small group learning enhances their ability to approach the problem from various perspectives and to apply scientific concepts to real life problems. Individual reports employed in the study played an important role in facilitating student ability to construct arguments by encouraging them to use data and evidence for their data and reasoning. The scaffolding used in the study assisted them to connect evidence and data to their claims.

Manjula (2013) developed interactive multimedia strategy for enhancing Critical thinking ability and Achievement in Mathematics of standard IX students. In the first stage of the study, the researcher prepared the interactive multimedia strategy for the few topics of mathematics based on standard IX syllabus. She also developed and validated the tool to assess the Critical Thinking Ability and Achievement in Mathematics. In the second stage the researcher checked the effectiveness of the developed multimedia strategy using experimental method among secondary school students from two private schools in Bangalore. One experimental group and control group were selected from each school (a total of 160 students). Then the researcher administered critical thinking ability test and Raven’s SPM to both control and experimental groups. Then the experimental group were taught using interactive multimedia strategy and the students of control group by conventional method. Later the investigator administered Achievement in Mathematics and Critical Thinking Ability Test to both experiment and control groups as post-test. After a gap of 20 days the researcher administered achievement in mathematics and critical thinking ability test to experimental group. During the third stage the investigator analyzed and interpreted the data using t-test, ANOVA and Pearson’s Product-moment Correlation. The findings revealed that the
multimedia developed were useful for enhancing the critical thinking ability and Achievement in mathematics of IX standard students. Also different levels of intelligence had a significant effect on the Achievement in Mathematics and critical thinking ability of students.

Oliveras and Marquez (2013) conducted a research to find out the use of newspaper articles as a tool to develop critical thinking in science classes. The aim of this research is to identify the difficulties experienced by secondary school students (aged 15 – 16) with the critical reading of newspaper articles with scientific content. Two newspaper critical reading activities in relation to the study of various scientific contents were designed and carried out in two schools (61 students in total), one with a student population from a medium to high social and economic bracket and the other students with a medium to a low social economic bracket. These activities were designed taking into account the phases of the reading process; before, during and after reading. In order to analyse the difficulties ‘elements of science Critical reading’ were identified on the basis of the ‘elements of reasoning’ of Paul and Elder and the categories proposed by Bartz C.R.I.T.I.C questionnaire and a scale was drawn up. The results show that the activities designed were useful in helping students to read critically. They also rated very positively the instrument created to assess the students’ answers: the scale based on the performance indicator of Paul and Elder. This instrument enabled them to detect the aspects of critical thinking where students have the most difficulties: identifying the writer’s purpose and looking for evidence in a text.

Patel (2013) developed a Critical Thinking programme for students of Standard IX and checked its effectiveness among them. The study was conducted in two phases. In the first phase, the investigator developed the programme and in the second phase the investigator checked its effectiveness on a sample of 53 Standard IX students of Anand district. To find the effectiveness, the investigator selected One-Group Pre test-Post test Design. The critical thinking test developed by the investigator was given as pre-test
and post-test. During the treatment, the Critical thinking programme was given to students and the effectiveness was found out using ‘F’ test. The findings revealed that the critical thinking programme developed was effective for enhancing the critical thinking of students. Also the critical thinking programme is equally effective for boys and girls in developing their critical thinking. Also Critical thinking of students (boys and girls) having high SES is higher than that of students having low SES. But it is effective for low SES students also as the post-test score is higher than the pre-test. Also Critical thinking of students (boys and girls) having high IQ is higher than that of students having low IQ. But it is effective for low IQ students also as the post-test score is higher than the pre-test.

Sulaiman (2013) conducted a case study at University of Malaysia Sabah on the effectiveness of PBL online on Physics students’ Creativity and Critical thinking. The study was conducted on a sample of 61 physics students from the School of Science and Technology of which 30 students belongs to the Experimental group and 31 students belongs to the control group. The experimental group was exposed to PBL online learning activities and the control group to traditional learning activities. Both groups were supported via an online learning environment. Students in the experimental group were again divided into 6 groups of 4-6 students. But for the traditional group, there were no groups involved, and they studied individually. Creativity of the participants were measured using the Torrance Test of Creativity Thinking (TTCT) and Critical thinking using the Watson Glaser Critical Thinking Appraisal (WGCTA). Both tests were administered as the pretest and posttest. The analysis using t-test and Mann-Whitney U test showed statistically significant differences in both creativity and critical thinking in favour of PBL group. The findings revealed that PBL online learning effectively improves Physics students’ creativity and critical thinking.

Deepa (2012) conducted a study to find out the effect of co-operative learning on Critical thinking and problem solving ability in Mathematics
among Higher Secondary School students. For this an experimental group (n=107) and a control group (n=107) were selected from two Government Aided Schools of Kanyakumari district. Equivalent group pre test – post test design was adopted to conduct the study. The tools constructed and validated by the investigator such as Critical Thinking test and Problem Solving Ability test in Mathematics were used as Pre-test and Post-test. The Jigsaw method developed by Aronson (1970) was applied to teach the experimental group. The control group was taught through the traditional method. An attitude scale towards co-operative learning approach prepared by the investigator was administered after the treatment to find out the attitude of students towards co-operative learning. The findings of this research revealed that Jigsaw method of co-operative learning approach improved the critical thinking and problem solving ability in Mathematics of Higher Secondary Students. The students who learned through the co-operative learning approach developed their critical thinking ability to higher level than that of those students who learned through the traditional method of teaching. Both, the urban and the rural, the middle and the low achievers benefited more from the co-operative learning approach in developing their critical thinking ability. Also the boys and girls of the Experimental group achieved better than the boys and girls of the control group.

Kishor (2012) conducted a study on Effect of Integrated Critical thinking Skills on Achievement in Physics of Senior Secondary School Students. The main objective of the present study was to study the impact of integrating CT skills on achievement in Physics and to find out the differences on CT skills based on gender. The study was conducted on 140 senior secondary school students of Rajasthan. The design selected was randomized pre-test – post-test control group design. The tools used were Physics achievement test and achievement test based on integrated CT skills. Both groups were pre- tested before starting the treatment and then the experimental group was taught using a package based on integrated CT skills and the control
group was taught using the traditional method. The tests were again administered as post tests. The analysis using t- test, ANOVA, ANCOVA and factorial design technique revealed that package of integrated CT skills has a significant impact on the achievement of XII standard students in Physics. Also there was significant difference between boys and girls on achievement test based on CT skills and not on achievement in Physics. Also boys showed better performance than girls on achievement based on CT skills.

Mitrevski and Zajkov (2012) conducted a study on the relationship between teaching methods and techniques and Critical thinking with special emphasis on laboratory method and practical work in teaching Physics. A parallel group design was used for conducting the study. The study was conducted on a sample of 163 students of 10\textsuperscript{th} grade of which 80 students belongs to control group and 83 students belongs to the experimental group. In the experimental group, Lab physics and practical work was used in teaching the unit “Electric current”. Many practical activities, such as demonstrations, conducting experiments and research activities also were used. The control group were treated in the traditional way. Students were pretested and post tested using CT test. But statistical analysis using t- test shows that it is not an effective method of teaching critical thinking skills and also no significant difference between male and female students in critical thinking skills.

Seeja (2012) conducted a study to find out the influence of active learning strategies on critical thinking, thinking styles and achievement in Physics among secondary school students. Lesson plans were prepared integrating active learning strategies like Think-Pair- Share, Group Investigation, Concept mapping, K-W-L and One minute papers for teaching Physics to the students of standard IX and its effect on the selected variables were studied. The design selected was pre-test, post - test non equivalent group design. During the treatment, Experimental group (N = 41) was taught using Active Learning Strategies for about five months and the control group ( N =
41) was taught using usual classroom practices like lecture, demonstration and group discussions. To collect the data, the investigator developed and validated the following tests like test on Critical Thinking Skills in Physics, Critical Thinking Dispositions Scale, Thinking Styles Inventory (adopted), Achievement Test in Physics and Students Reaction Scale. These tools were administered as pre- test and post- test. The collected data were analysed using statistical techniques like ANCOVA, ANOVA, t-test and Partial Correlation. Qualitative data were analysed using percentage analysis. The results revealed that Active Learning Strategies were effective in enhancing the Critical Thinking Skills, Critical Thinking Dispositions, Legislative Thinking Styles, Judicial Thinking Styles and Achievement in Physics among secondary school students. The study also showed a positive significant correlation between Critical Thinking Skills and Critical Thinking Dispositions, Critical Thinking Dispositions and Judicial Thinking style, Critical Thinking Skills and Achievement in Physics and Judicial Thinking Styles and Achievement in Physics

Krishnan (2011) conducted a study to find out the effect of Blended learning strategy on higher order thinking and learning science among secondary school students. The investigator selected pre test-post test non-equivalent groups design to conduct the study. The investigator selected two CBSE schools using purposive sampling technique from Bangalore City. One school having the provision of online learning platform ‘www.thinkquest.org’ were selected as the experimental group (N =38) and another school, without the online learning platform were selected as the control group (N= 36).The experimental group was taught six units of science using blended leaning strategy whereas the control group was taught the same science units by the regular teacher using the conventional method of teaching. The results of the study revealed that blended learning strategy is effective than the conventional method of teaching in enhancing critical thinking, problem solving, science process skills and science achievement among secondary school students. It is
found that there is no difference in critical thinking among visual, auditory and kinesthetic secondary school students; that is blended learning strategy was found to be equally effective in improving critical thinking of experimental group students irrespective of their learning styles.

Vieira, Tenreiro Vieira and Martins (2011) presented a paper on Critical Thinking: Conceptual Clarification and its importance in Science Education. In the paper the author gives a brief description about the origin of Critical thinking, reason’s for educational interest in Critical Thinking, Critical Thinking and Science Education, Critical Thinking, Scientific Literacy and Competencies, Promoting CT in Science classrooms, teaching strategies for CT and factors that hinders the promotion of Critical thinking. Also the author suggested to direct the teacher education and pedagogical practices towards the development of CT and also suggested the need of an education policy for the promotion of CT.

Smitha and Rao (2011) conducted a study to find out the Relative Effectiveness of Inquiry Training model and Guided discovery learning on Critical thinking of Secondary School Students. The design selected was pretest – post test non equivalent group design 3x2 factorial matrix. The sample for the present study was 126 students belonging to the three different sections of the eighth standard of a Govt. Vocational H.S.S in Kozhikode district. Two classrooms containing 42 students each were the Experimental groups. They were taught using the Inquiry Training Model and Guided Discovery Learning. The third classroom was taken as the control group (n=42) which received classes based on conventional lecture cum demonstration method. A critical thinking test developed by the investigator based on the components proposed by Delphi Report (1990 was given) as pre-test and post test. Also a semi structured interview was used to gather the students’ reaction on the instructional methods used the role of the teacher, the classroom environment, and the role of the students. The analysis of the data using ANCOVA revealed that both Inquiry Training Model and Guided Discovery Learning were equally
effective in developing Critical thinking in students and both these approaches were better than the conventional lecture demonstration method.

Bensley, Crowe, Bernhardt, Buckner and Allman (2010) wrote an article in which they gave Seven Guidelines for explicit instruction in which instructors can directly infuse CT skills and assessment into their courses. With this direct infusion approach, instructors can use relevant content to teach CT rules and concepts along with the subject matter. This guidelines inspire the students to think critically, Clearly state the CT goals and objectives for the class, provide procedures to infuse CT that fit content and skill requirements of the course, use guided practice, provides the procedure to explicitly modelling and scaffolding CT, Align assessment with practice of specific CT skills, necessary rules to Provide feedback and encourage students to reflect on it and Reflect on feedback and assessment results to improve CT instruction. They compared the acquisition of critical thinking skills using 3 groups of research methods students. The first group get critical thinking skills infused directly into their course and the other two groups get no explicit critical thinking skills instruction. They found that the group receiving explicit critical thinking skills instruction showed significantly greater score in their argument analysis skills than the other two groups receiving no explicit critical thinking instruction. These result revealed the effectiveness of explicit teaching of critical thinking skills infused directly into regular course instruction.

Boulter (2010) conducted a study to examine the influence of Socratic Questioning in online discussions on the critical thinking skills of undergraduate students. The study was conducted on Undergraduate students enrolled in a proprietary institution with non selective admission criteria. The sample constitutes 25 students selected purposively from two sections with the view that these students possess critical thinking skills. They were randomly assigned to Experimental and control groups. California Critical Thinking test were administered as Pre-test and Post test. Then the Experimental group received instructor facilitated Socratic questioning in online discussion and the
control group discussed in traditional way. The data were analysed using qualitative and quantitative techniques such as t-test, chi-square test and Wilcoxon test. The findings revealed that Socratic questioning compared with traditional instructional methods did not have a statistically significant influence on the critical thinking of students with diverse critical thinking skills.

Gurubasappa (2010) conducted a research to find out the effect of Critical thinking, Emotional intelligence and Creativity on Academic achievement in Science of Secondary School Students. Survey method was adopted to conduct the study and the sample selected were 600 secondary school students of Tumkur District. The data were collected using Critical Thinking Test in Physics (CT-TIP), Emotional Intelligence Inventory, Creativity test, Socio economic status scale and Achievement in Science. The results reveal a high positive correlation between Critical thinking and academic achievement. Also academic achievement of high level critical thinking students is higher than that of moderate and low level critical thinkers. It was concluded that Critical thinking and Socio – economic status are significant predictors of academic achievement, but emotional intelligence and creativity are not the significant predictors of academic achievement.

Abrami, et al. (2008) conducted a meta analysis to study the instructional interventions affecting the Critical Thinking skills and dispositions .They found that training in Critical Thinking works. They found that developing CT skills separately and then applying them explicitly to course content works best. When instructors received special advanced training for teaching CT skills, the effect of the interventions were greatest. So it is recommended that educators must take steps to make objectives of CT explicit in courses and integrate them to both pre-service and in-service training and faculty development.

Hayes and Devitt (2008) studied the effect of classroom discussion with student led feedback on the development of Critical Thinking skills. The
study was conducted on 74 students enrolled in an introductory course in food science of Purdue University. Classroom Discussion with Student Feedback (CDSF) was employed to develop the critical Thinking of Students. The treatment was conducted for 50 minutes per week for 14 weeks. During the treatment students were divided into smaller groups and scenarios were discussed in these groups. The ACT-CAAP critical thinking test developed by Purdue University was used to analyse the Critical thinking of students. The scores were analysed using t-test and ANOVA and found that small group discussion was an effective tool for developing Critical Thinking of students. CDSF strategy was successful in development of Critical Thinking skills among students.

Simpson and Courtney (2008) conducted a study on implementation and evaluation of Critical Thinking strategies to enhance Critical Thinking skills in Middle East Nurses. Critical thinking strategies such as questioning, debate, role play and small group activities were developed and implemented on a sample of 20 Middle East Nurses who were attending a professional development programme. This programme successfully integrated critical thinking strategies into the curriculum and were designed to promote critical thinking skills, problem solving, development of clinical judgement making and care prioritization. In order to encourage classroom interaction, the classroom used for this programme was arranged in a ‘U’ shape, which allowed all participants to have eye contact and to question and interact with each other. Direct participation observation including watching interactions, and behaviours, listening, asking questions and examining materials were undertaken and also separate focus group interviews were undertaken with nurse educators as well as students to compare levels of satisfaction. From the interview the investigator got a clear idea that critical thinking can be developed in teachers while preparing the lessons using these strategies and can be developed among students using these methods. Also students respond that Group work and questioning were the best and then the debate and role play in
developing intended CT skills. In short, the intervention programme was successful in developing critical thinking skills in both the nurse educators and student nurses in this programme.

Sullivan (2004) conducted a study to find out the effect of dialogue and group interaction during collaborative examinations to enhance the Critical Thinking of Students. It was found that critical thinking skills were enhanced during dialogue and group interactions. The study provide opportunity for students to realize the benefits of group work while receiving immediate feedback on performance and participating in their own formative assessment.

Walker (2003) reviewed ERIC from 1933 to 2002 to find out the articles and studies related to Critical Thinking to define the concept, to find out the Critical Thinking Dispositions and to find out the active learning strategies that promote Critical Thinking. He found that numerous instructional methods exist to promote thought and active learning in classroom including case studies, discussion methods, written exercises questioning techniques and debates. These strategies are not appropriate for all subject matters and classes, but they can be used and adapted to facilitate Critical Thinking and active participation of students.

Bailin (2002) presented a paper on Critical Thinking and Science Education. This paper analysed the misconceptions in the characterization of Critical thinking in terms of processes or Skills. The paper suggested contextual nature of Critical Thinking as it takes place in response to a particular problematic situation, task, question, etc which includes concepts, criteria, and habits of mind as well as background knowledge. It offers a philosophically sound and justifiable conception of critical thinking and demonstrates how this conception could be used for Science education. It also gives a brief description about CT and the need for applying it in Science education.

Paul and Elder (2001) wrote an article on Critical Thinking in daily Life. Article starts with the fact that most of us have great capacity, but most of
it is undeveloped and dormant. The article presents six stages for our development as a Critical thinker. They are 1) the Unreflective thinker (unaware of significant problems in our thinking), 2) the Challenged thinker (aware of problems in our thinking), 3) the Beginning thinker (try to improve our thinking but without regular practice), 4) the Practicing thinker (recognize the necessity of regular Practice), 5) the Advance thinker (skilled and insightful thinking). Also nine Strategies were given in this article that any person can use to develop as a critical thinker. They were 1) use “wasted” time, 2) A problem a day 3) Internalize Intellectual Standards, 4) Keep an intellectual journal, 5) Reshape your character, 6) deal with your ego, 7) Redefine the way you see things, 8) Get in touch with your emotions, 9) Analyze group influences on your life.

Tiwari, Chan and Sullivan (1999) presented a paper on, Enhancing Student’s Critical Thinking through Problem – Based Learning. The purpose of this paper is to report how Problem Based Learning help to reduce deficits in Critical Thinking. California Critical Thinking Disposition Inventory (CCTDI) and Holistic Critical Thinking Scoring Rubrics (HCTSR) were used to measure the Critical Thinking of Students and was administered as pre test and post test. The time series design was selected for the study. In this study, Student’s Critical Thinking was assessed before the implementation of Problem Based Learning (independent Variable). After the completion of PBL test was again administered at six – monthly intervals for the next eighteen months. The purpose of this is to monitor the effect of PBL after the intervention period. The analysis showed no significant improvement in relation to advancing age. Overall students were also weak in their Critical Thinking Skills.

Murthi (1998) conducted a study on the effect of specialized critical thinking skills of teachers on the academic achievement of students. The chief objective of the study was to investigate whether there were significant differences in the academic achievement of students who were taught by
teachers who had received specialized critical thinking skills training and students who were taught by teachers who had not received such training. The study was conducted on a sample of 893 middle school students in grades 6 and 8. The findings indicated that there was significant difference in the achievement of experimental and control groups of sixth grade students and there was no significant difference in the achievement of experimental and control groups of eighth grade students.

Gokhale and Anuradha (1995) conducted a study to examine the effectiveness of individual learning versus collaborative learning in enhancing Critical thinking skills and drill – and – practice skills. Pre-test, Post-test non equivalent group design was used for the study. A test based on series and parallel DC circuits were administered as Pre-test and Post test. t – test, ANCOVA and correlation statistics were used for data analysis. The results revealed that the drill – and – practice skills and critical thinking skills of participants that studied collaboratively were slightly higher than those who studied individually.

Kezar (1992) conducted a study to find out the effect of computer technology and traditional methods of instruction upon the CT skills of teachers and students. The objectives of the study were 1) To investigate the effectiveness of computer technology in developing critical thinking skills of teachers and middle school students. 2) To examine the relationship between achievement test scores and critical thinking scores, 3) To investigate the influence of years of experience and educational degrees of teachers upon teacher gain in critical thinking and students gain in critical thinking. The findings showed that the computer group performed significantly better than the traditional group in achievement test and critical thinking test. Also there was a significant inverse relationship between years of teaching experience and gain scores of students. Students of teachers with the fewest years of experience had the highest gain scores.
Summary

The investigator thoroughly analysed various literature including studies and articles related to the variable Critical Thinking. Sherafat (2016) and Gurubasappa (2010) stressed the positive effect of Critical Thinking on Academic achievement of Students, but Abrami et al. (2008) and Murthi (1992) found that the Academic Achievement of students will be increased if the teachers are specialized in Critical thinking.

Santos (2017), Vieira, Tenreiro & Martins (2011) and Bailin (2002) identified the influence of Critical Thinking on Science Education of Students whereas Arulselvi (2016), Kishor (2012) and Rodrigues and Oliveira (2008) identified more specifically that integrating Critical thinking skills enhances Achievement in Physics of students both at secondary and senior secondary level. Kezar (1992) identified that the use of Computer technology enhances the Critical Thinking of Students. Patel (2013) and Manjula (2013) identified that Critical Thinking of high IQ students is higher than that of average and low IQ.

The investigator found controversy regarding Gender difference on Critical Thinking skills. According to Kishor (2012) the Critical thinking skills of Boys is higher than that of girls but Arulselvi (2016) and Mitrevski and Zajkov (2012) identified no gender difference in the Critical thinking Skills. The controversy also exist regarding the Problem Based learning (PBL) on Critical Thinking of Students. According to Tiwari., Chan and Sullivan (1999) PBL is not effective to enhance Critical Thinking of Students. But Sulaiman (2013) and Mundilarto &Ismayo (2017) identified the positive effect of PBL on Critical Thinking of Students. Socratic questioning was widely accepted as a technique to enhance Critical Thinking of Students at various levels, but Boutler (2010) revealed that it was not an effective technique to enhance Critical Thinking.
The investigator identified various models, techniques and strategies that enhanced Critical Thinking of students at various levels. They are Guided Inquiry Learning model (Nisa, Koestiari, Habibulloh and Jatmiko, 2018), Problem Based Learning (Mundilarto and Ismoyo, 2017 and Sulaiman, 2013), Inquiry-discovery model (Wartono, Hudha & Batlolona, 2017), Inquiry based learning approach (Duran, 2016), Socratic Seminar (Kalelioglu & Gulbahar, 2014), Portfolio based Physics learning model (Amin, 2013), small-group learning with authentic tasks, individual writing and scaffolding (Kim, Sharma, Land and Furlong, 2013), Interactive multimedia strategy (Manjula, 2013), Co-operative learning (Deepa, 2012), Think-Pair-Share, Group Investigation, Concept mapping, K-W-L and One minute papers (Seeja, 2012), Blended learning Strategy (Krishnan, 2011), Inquiry Training model and Guided discovery learning (Smitha and Rao, 2011), Classroom Discussion with Student led feedback (Hayes and Devitt, 2008), Dialogue and Group Interactions (Sullivan, 2004), and Collaborative learning (Gokhale, Anuradha, 1995).

3.4 ACHIEVEMENT IN PHYSICS

Majority of the literature presented under Critical Thinking and Problem solving Ability are related to Achievement in Physics also. Therefore the investigator presented below only those studies other than that described under Critical Thinking and Problem Solving Ability in relation to Achievement in Physics. The studies were presented below in the chronological descending order.

Asikoy and Sorakin (2018) conducted a study to find out the effect of Clicker Aided Flipped classroom model on Achievement, Anxiety and Students’ perception in Physics. The study was conducted using Pre –test, Post-test Control group design on a sample of 61 students (Experimental, n=31 and Control, n=30) of first year engineering at Near East University. The students were randomly assigned to the Experimental and control group. The
investigator developed a learning management system (Moodle) for the experimental and control groups. Both the experimental and control group watch the video uploaded on the page 2 days prior to the lecture time. Then Experimental group received classes using flipped classroom model during the class time and normal procedure is followed in the control group during the class time. Both the groups were pre-tested and post tested using Physics Achievement test and Physics anxiety questionnaire. The results revealed that the use of Clicker Aided flipped classroom model enhanced the Achievement in Physics of the Experimental group more than the control group. Also the physics anxiety level of Experimental group decreased significantly than those in the control group.

Saleh and Subramaniam (2017) conducted a study to find out the Effect of Brain-Based Teaching Method on Physics achievement among ordinary school students. This study aimed to determine whether there exist significant difference in Physics achievement between those who were exposed to the Brain-Based Teaching Method (BBTM) and those who followed the conventional teaching method (CTM), and between males and females who were exposed to the BBTM. The investigator selected Quasi – Experimental Research Design and the sample constituted 90 students from two ordinary schools in Penang, Malaysia. Data collected through the Physics Achievement Test (PAT) were then analyzed descriptively and inferentially. The results showed that students who were exposed to the BBTM obtained a significantly higher mean score in the PAT compared to those who followed the CTM. It was also found that there was no significant difference in the PAT means scores between male and female students in the BBTM group. These findings indicate that BBTM was effective in improving Physics achievement as well as in reducing the gender gap in Physics achievement among ordinary school students.

Sari, Hassan, Guven and Sen (2017) conducted a study to find out the 5E Teaching Model using Interactive Simulation on Achievement and Attitude
in Physics Education. Quasi Experimental Research design was selected to conduct the study. The study was conducted on two Eleventh Grade Science stream classes with 80 students. The experimental group was taught using the 5E teaching model using Interactive Simulation and the control group using the traditional method. The data was analysed using independent sample ‘t’ test. The results revealed that the 5E learning cycle model integrated with simulations enhanced the achievement in Physics better than the traditional method.

Keller, Neumann and Fischer (2016) conducted a study to find out the impact of teachers’ pedagogical content knowledge and motivation on students’ achievement and interest in Physics. The investigator used a Multi method approach for conducting the study. For the study, the investigator selected a sample of 77 Physics teachers and their classes from Germany and Switzerland. Data was collected using teacher pedagogical content knowledge test, students achievement test, teacher motivation questionnaire and student interest questionnaire. The results revealed that both teachers’ knowledge and their motivation improve students’ achievement and interest in the subject.

Turgut, Colak and Salar (2016) conducted an action research to find out the effect of 7E model on conceptual success of Students in the unit of electromagnetism. The study was conducted on a total sample of 52 students of grade 11 of two separate classes in a High School at Turkey. The data were collected using worksheets, open-ended and multiple choice achievement test and personal interviews. The worksheets were prepared based on the 7E learning model. 6 students with high, average and low level of mental ability were interviewed to find out their achievements. The activities and materials applied were found to be effective on conceptual development and in eliminating misconceptions in electromagnetism.

Karagoz and Saka (2015) developed teacher guidance materials based on 7E learning method in Virtual environment with an intention to eliminate the difficulties in Conventional laboratory applications. Here the experiments
are supported with technological means and carried out using a computer Software with an internet. The material was developed for the chapter “Electric Current” of the Secondary Education Physics Course. The present study was intended to evaluate these materials by the teachers and experts in the field of Physics Education. Case study method was employed. 4 physics education specialist, 6 physics teachers and 1 electricity teacher took part in the study. The Opinions of them were obtained using the Course material Evaluation Scale and semi structured interviews. The materials developed were found to be effective.

Njiru and Karuku (2015) conducted a case study to explore the factors that contribute to low performance in Physics in Kenya. To conduct the study, the investigator adopted a mixed method approach where both qualitative and quantitative methods were used to gather data. The participants were two Physics teachers ( a male and a female) and 57 physics students ( 30 males and 27 females) from a Government co educational secondary school located in Kenya. Three major categories of factors were identified as contributing to students’ low performance in physics; namely, learning factors, teaching factors, and administrative factors. Learning factors includes time management skills and background knowledge in mathematics; teaching factors includes quality of teacher-student interactions and teacher’s content knowledge; while administrative factors includes the administrative context within the school, such as access to resources and quality of guidance provision.

Radhakrishnan (2015) developed a Web Based meaningful engaged learning strategy and found its effectiveness for learning Astronomy at Secondary Level. The investigator adopted Experimental method to find out its effectiveness and the design selected was Pre-test, Post-test non equivalent group design. The investigator conducted the study on a total sample of 640 students of which 320 students belongs to Standard VIII and 320 students belong to Standard X. The Experimental group in each standard was taught using the developed web based meaningful engaged learning strategy and the
Control group using the present Activity Oriented Method. The Achievement Test in Astronomy, test of Reasoning Ability in Science and Scientific Attitude Scale were administered as Pre-test and Post-test. The data collected were analysed using ‘t’ test and ANCOVA. The results revealed that the Achievement in Astronomy, Reasoning Ability in Science and Scientific Attitude of students taught using the Web Based meaningful engaged learning strategy is significantly higher than that of those taught using the existing Activity Oriented method.

Adeyemo and Babajide (2014) conducted a study to find out the effect of Mastery Learning Strategy on Achievement in Physics of Senior Secondary School Students. The study was conducted on a sample of 160 Secondary School Students of Lagos State selected using Stratified Random Sampling Technique. The design selected was Pre- test Post-test non equivalent group design. The tools used were Physics Achievement Test and a questionnaire to measure the attitude of Students towards Physics. Both groups were pre – tested, then the Experimental group received classes in MLA teaching method and the Control group in Conventional method of teaching. After the treatment both groups were post – tested. The data were analysed using t – test, Pearson’s Product moment Correlation and ANOVA. The results revealed that students in the Experimental group performed better than the Control group. Also students with positive attitude towards Physics performed better than Students with negative attitude. So it is recommended that MLA should be encouraged in Schools to enhance Achievement in Physics and Positive attitude towards the subject.

Erinosho (2013) conducted a study that aimed to find out the difficulties that students face while learning Physics and the reason behind this difficulty. A questionnaire was administered to 830 (306 females and 524 males) final year students in science class and 52 physics teachers purposively drawn from secondary schools in Ogun and Lagos States, Nigeria. The findings show three major sources of difficulty in learning physics as related: nature of
subject, teaching/teacher factors and curriculum/assessment. Students were found to have difficulty understanding specific topics in the curriculum that are usually characterized as lacking concrete examples and requiring a lot of mathematical manipulations or visualization. Majority responded that the difficulty in solving problems alone and asking questions in class. The findings have implications for designing interventions and identifying pedagogical techniques that help students overcome the underlying sources of difficulty that impede quality learning.

Rajasree (2013) conducted a study to find out the effect of Mc Comark and Yager Taxonomy in teaching Physics at Secondary Level. The investigator adopted pre-test, Post-test non equivalent group design for the study. The study was conducted on sample of 340 students (170 students each in the Experimental and Control group) of standard X of Alappuzha district. The investigator compared the Mc Comark and Yager Taxonomy with Bloom’s Taxonomy. Achievement test in Physics, Physics Interest Inventory, Scientific attitude scale, Science creativity test and science process skills test were administered as pre-test and post-test to both the groups. In between the experimental group was taught using the Mc Comark and Yager Taxonomy and the Control group using the Bloom’s Taxonomy. The scores obtained were analysed using ‘t’-test and ANCOVA. The results revealed that the Achievement in Physics, Physics interest, scientific attitude, science creativity and Science process skills of students taught using the Mc Comark and Yager Taxonomy is significantly higher than that of those using the Bloom’s Taxonomy.

Senan (2013) conducted a study that described the effectiveness of Cognitive Development Model on Achievement in Physics of Students. The design selected was pre-test, post-test parallel group design. The study was conducted on a sample of 90 students of standard IX of which 45 students belong to the Experimental group and 45 students belong to the control group.
Both the groups were pre-tested. Then the Experimental group was taught using the Cognitive development model and the control group using the conventional strategy. Both the groups were post-tested after the treatment. The data obtained was analysed using ANCOVA. The results revealed that the experimental group was superior to the control group in post-test Achievement. Thus the Cognitive Development model was found to be effective.

Bautista (2012) conducted a study to find out the effect of Personalized Instruction on Academic Achievement of Students in Physics. The Quasi-Experimental design was used in the study. The sample selected was 78 first semester students Cagayan Valley Computer and Information Technology College, Philippines. The students in the Experimental group were initially divided into high ability, average ability and low ability students based on their scores in Achievement. Then they were grouped. Each group contains 4 or 5 students. Then they received personalized instruction with the help of Co-operative learning and Buzz sessions. Students in the Control group received normal treatment. The results revealed that personalized instruction is better than conventional method in enhancing Achievement in Physics of students.

Adeyemo (2010) conducted a study to find out the impact of background and classroom correlates on Students Achievement in Physics. The investigator conducted the study on a selected sample of 200 Senior Secondary School students selected randomly from five Senior Secondary Schools in Nigeria. Physics classroom Observation Schedule (PCOS) and Classroom Interaction Questionnaire (CIQ) were the two instruments used for the study. The data collected were analyzed using SPSS (Mean, SD, simple Regression and ANOVA). The result of the findings showed that background and classroom correlates have significant influence on students’ achievement in physics.
Summary

The factors that contribute to poor performance in Physics identified were time management skills and background knowledge in Mathematics (Nijru and Karuku, 2015), teacher factor (Nijru and Karuku, 2015 and Erinosho, 2013), Assessment (Erinosho, 2013) and administrative factors (Nijru and Karuku, 2015). Also Adeyemo (2010) identified that background knowledge and classroom correlates have significant influence on Students achievement in Physics. Keller, Neumann and Fischer (2016) identified that teachers’ pedagogical content knowledge and motivation improves students’ Achievement and Interest in Physics.

Clicker Aided Flipped Classroom Model (Asikoy and Sorakin, 2018), 5E Teaching Model with Interactive simulations (Sari, Hassan, Guven and Sen, 2017), 7E Model (Turgut, Colak and Salar, 2016 & karagoz and Saka, 2015), Brain Based Teaching method (Saleh and Subramaniam, 2017), Web-based Meaningful Engaged Learning (Radhakrishnan, 2015), Mastery Learning Strategy (Adeyemo and Babajide, 2014), Mc Comark and Yager Taxonomy (Rajasree, 2013), Cognitive Development Model (Senan, 2013) and Personalized Instruction (Bautista, 2012) were found to enhance the Achievement in Physics of students in addition to all those methods and techniques summarized under Critical Thinking and Problem Solving Ability.

Conclusion

According to Ausubel, ‘No knowledge is new knowledge. It is only the extension of old knowledge’ (as cited in Scaria, 2016). From the review of related literature the investigator got a clear picture regarding Andes Intelligent Tutoring Systems – its design and development, Critical thinking – strategies, tools and techniques, and Problem Solving ability. In the light of this the investigator designed the plan and procedure of the study and the details are given in the successive chapters.