CHAPTER – V
SUMMARY AND DISCUSSION

5.1 INTRODUCTION

This chapter discusses genesis of the problem, statement of the problem, objectives of the study, procedural details of the study, analysis of data, findings of the study, discussion and implication of the study and suggestions for further research.

5.2 GENESIS OF THE PROBLEM

We are so accustomed to live in a world of science that we seldom stop to think about how science is constantly changing our way of life. The vast and explosive scientific and technological revolution has produced a fantastic growth of scientific knowledge in most fields of human activity. As the world moves towards an ever more global economy, many societies are experiencing a change in the ability profile of their human resource needs. Therefore, education system is confronted with pressure to adopt educational programmes that reflect new ways of learning.

Learning is a journey and has intrinsic merit if it moves in the right direction, thus requiring frequent shifting in many things. Developing the right learning paradigm is of utmost importance. Learning paradigm which frames learning holistically recognizes that the chief agent in the process is ‘learner’ who constructs knowledge out of his or her own experience.

Learning science is something students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others. Understanding science requires integration of a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, ways to use the ideas to explain and predict natural phenomena, and ways to apply those ideas to many events. The construction of deep scientific knowledge results from actively practising science in a structured learning environment and therefore it is essential to present and project science as a process of constructing knowledge. To encourage
independent learning in science, the inquiry aspect of science should be related to the structure of scientific knowledge and the investigative strategies of science.

Recent developments in the field of Information and Communication Technology (ICT) are revolutionary in nature. ICT is not an initiative introduced purposefully into an existing system in order to bring about improvement, but a major perturbation that has established the existing order and led to a large number of unpredictable changes (Somekh, 2007). The ability to use ICT effectively and appropriately is essential to enable learners to acquire and exploit information within every sphere of human activity. ICT has paved the way for accelerating the paradigm shift through providing more flexible ways of learning. This provides learners more ways to search for the most effective and efficient path to learning. The ready availability of computer technologies in the classroom and the community has greatly expanded the educational options available to learners.

ICT has an important role to play in science teaching and learning. In recent years, there has been a shift towards the use of ICT skills as tools to assist learning science. Researches suggest that ICT can be used to strengthen procedural knowledge and that the main forms of ICT, which are relevant to school science activity, include: multimedia software, information systems, publishing and presentation tools and computer projection technology (LaVelle & Brown, 2003; Osborne & Hennessy, 2003). ICT can provide access to a wide range of resources that are of high quality and relevance to scientific learning. ICT widens the range of materials that can be used in teaching and learning to include text, still and moving images and sound, and increases the variety of ways that the materials can be used for whole class and individual learning (Eggert, Meyvant & Allyson, 2008). Hence technology should be used not only as a teaching aid but also as a starting point from which to develop scientific concepts. Activity started in one classroom session can be continued later using the potential of ICT. But the challenge is to effectively integrate face-to-face instruction with ICT for optimizing science learning. ICT should be used in alignment with existing pedagogical practice or the pedagogy should be restructured or evolved to incorporate the benefits of using ICT in science learning.

Online learning is gaining its popularity in K-12 education because of its unique abilities to provide rich student-teacher-peer interaction, to provide students with enriched learning experiences, to extend learning beyond the school day, and to support more successful differentiated learning strategies that personalize students’
educational experiences. At the same time, in an age when information and communications technology skills are so critical, and so much collaboration, resource sharing, content development and learning can be done digitally and asynchronously, it is unlikely that student learning will continue to be based solely on printed textbooks and face-to-face classes. Teachers in schools also have increased their use of internet-based content and resources in their classrooms. This evolution has often been driven by a few tech-savvy teachers who seek new ways to provide enriched content and to extend learning beyond the walls of the school and confines of the school day. This has spurred the creation of programmes which blend online learning and face-to-face instruction and thus blended learning evolved.

Blended learning is a hybrid of online learning and Face-to-Face (F2F) instruction using a variety of learning resources. Blended learning is a flexible learning strategy that integrates innovative and technological advances of online learning with interaction and participation of traditional classroom learning. Combining face-to-face and fully online components optimizes both environments in ways impossible in other formats (Dziuban, Hartman & Moskal, 2004). Garrison and Vaughan (2008) defines blended learning as a new educational paradigm that integrates the strengths of face-to-face and online learning — a design approach whereby both face-to-face and online learning are each made better by the presence of the other. Providing several online options in addition to traditional classroom training actually increased what students learned (Dean, Stahl, Sylvester & Pearson, 2001; Graham & Allen, 2005). It is an educational formation that integrates online learning techniques including online delivery of materials through web pages, discussion boards and/or email with traditional teaching methods. The pedagogy of blended learning is based on the assumption that there are inherent benefits in face-to-face interactions as well as the understanding that there are advantages in using online methods (Clark & Patrick, 2007).

Blended learning, the teaching practice that combines teaching methods from both face-to-face and online learning, is an established, rapidly growing instructional model that is proving to be highly effective in helping schools and districts address the challenges of student achievement, limited resources, and the expectations of 21st century learners (Eduviews, 2009). Ingredients of blended learning are live events, self-paced learning, collaboration, assessment and performance support. With the growth of blended learning, pedagogy of blended learning is also evolving. The role
of teacher is getting transformed from ‘lecturer’ to ‘mentor’ who gives continuous support, guidance and assistance. The blended learning models are so flexible and adaptive that teachers can create instructional activities that give students opportunities to work collaboratively, tapping their interests and abilities in social learning (Eduviews, 2009).

A good merit of blended learning is that it can cater to individual preferences or learning styles. Students are free to choose their preferred learning style to some extent though some components may be compulsory (Harding, Kaczynski & Wood, 2005). Thus differentiated instruction is possible to a large extent. Self-pacing allows for the engagement of every learner at any given time in blended learning. Students also realize that the learning involved becomes a process, and not just isolated individual learning tasks. One of the most specific advantages is the opportunity to quickly establish a sense of community amongst student learners (Garrison & Kanuka, 2004).

Within the blended learning classroom, students meet in face-to-face instruction, and then have opportunities to collaborate and communicate with open dialogue, to experience critical debate through a world wide online platform which in turn facilitates greater reflection on part of the learners. Blended learning approach provides room for the development of autonomy, self-efficacy and individual organizational skill since it gives scope for self regulated learning, in effect contributing to the development of higher order thinking.

Higher order thinking is thinking on a level higher than memorizing facts or telling something back to someone exactly the same way it was told. When a person memorizes and gives back the information without having to think about it, we call it ‘rote learning’. Higher order thinking takes thinking to levels higher than just restating the facts. It requires that we do something with the facts. We must understand them, connect them to each other, categorize them, manipulate them, put them together in new or novel ways, and apply them as we seek new solutions to new problems. Learners need to work out the problems systematically and logically and come to a satisfactory conclusion.

A study conducted by Raths, Jonas, Rothstein and Wassermann in 1967 (as cited in Carr, 1990) asserts that higher-order thinking can be a part of our curriculum, but it requires moving beyond the traditional lecture and exam mode to encourage it. In every course, and especially in content subjects, students should be taught to think
logically, analyze and compare, question and evaluate. Skills taught in isolation do
little more than prepare students for tests of isolated skills (Spache & Spache, 1986).
When students really ponder over a question, discuss it in groups, or explain their
answers to others, they are more likely to use skills at advanced levels of critical
thinking and they become better problem solvers in the process.

Critical thinking is a mode of thinking about any subject, content or problem
in which the thinker improves the quality of his or her thinking by skillfully taking
charge of the structures inherent in thinking and imposing intellectual standards upon
them (Cascini & Rich, 2007). Studies conducted by Raths, Jonas and Rothstein in
1967 (as cited in Carr, 1990) and Ennis (1990) suggest that development of these
skills is best done in association with specific content or within specified domain of
knowledge. Therefore development of critical thinking should be integrated into
all courses and in all classroom areas – lectures, discussions, homework, writing
assignments etc (Bowers, 2006). Bransford, Vye, Kinzer and Risko (1990) suggest
that one way to help students develop critical thinking skills is to focus on problems
or cases where they are challenged to deal with real data and experiences. Therefore
teachers would benefit the most by having access to discipline specific learning
activities that they can seamlessly integrate into their courses.

Critical thinking is best taught through an experiential learning process. This
approach rests upon experiential and constructivist learning models and encourages
instructors to fully engage students in the learning process. (Otten & Leszczenski,
2006). Not surprisingly, excellence in science teaching focuses on the development of
students’ critical thinking skills. Many researches indicate that the use of problem
solving instructional models and techniques to teach science influence the problem
solving skills of students. Problem solving skills are promoted by providing an
environment rich in potential for exploration and by encouraging students to reflect on
their actions (Hass & Parkay, 1993).

Learning science is never only about learning to know the natural world. In
conjunction with the proposed definition that learning in general is a measurable
change of behaviour, a further distinction between what one learns and how one
learns is useful. It is of value to consider the processes of science as well as the
products of science. Science education should be aimed at preparing students for both.
The learner should not only gain knowledge of the content of science but also develop
sophistication in his or her use of the logical skills by which this content is
accumulated. In effect, the learner must learn ‘how to learn’ along with acquisition of facts and concepts in science. Product and Process aspects of science are interdependent and complementary to each other. Both factual and conceptual approaches to science teaching emphasize the ‘product of science’.

Process aspects of science include the ways in which the products were formulated. Science learning and the development of science process skills are integrated activities. While the process skills are to be viewed as central to school science education and important enough to be taught in their own right, they ought to be combined with science content in order to enable students to learn both science processes and content at the same time – in a seamless learning experience. The knowledge of the product is useful in understanding the process of science and for concretizing the process for pedagogical use (NCERT, 1982).

The curriculum project, Science – A Process Approach [SAPA] by commission on Science Education by American Association for Advancement of Science [AAAS] in the early 1960s rejected the idea that science is only a collection of facts; de-emphasized content and focused on the process of knowing. They defined process skills as a set of broadly transferable abilities appropriate to many science disciplines and reflective of true behaviour of scientists. These skills are best thought of as a set of intellectual skills that are essential for acquiring reliable information about nature.

The major goal of SAPA is to develop learners’ skills in using these processes of science. They classified science process skills into basic science process skills and integrated science process skills. Basic science process skills include observing, classifying, measuring, communicating, inferring, predicting, using space/time relationships and using numbers. Integrated science process skills include formulating hypotheses, controlling variables, interpreting data, defining operationally and experimenting. Researches suggest that appropriate kind of instruction can be successful in developing science process skills. Therefore, it is very essential to provide students with opportunities to explore nature. This helps in developing science process skills among them.
5.3 NEED AND SIGNIFICANCE OF THE STUDY

Organization of learning process has been characterized from the past as predominantly ‘teacher controlled’. If education is to provide an adequate preparation for the ‘information society’, schools should empower learners to become more active and responsible so that they can acquire productive skills and higher order thinking skills. Paradigm shift of learning ensures to focus learning on knowledge construction rather than rote memorization of facts. Therefore more emphasis should be given to those modes of learning where self-regulation and authentic learning are possible.

Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world. Higher-order thinking requires students to manipulate information and ideas in ways that transform their meaning and implications. Critical thinking, one of the important higher order thinking skills is a pervasive and self-rectifying human phenomenon, which constitutes interpretation, analysis, evaluation and inference. Critical thinking is best taught through an experiential learning process. This approach rests upon experiential and constructivist learning models and encourages instructors to fully engage students in the learning process (Otten & Leszczniski, 2006). Research into problem solving has indicated that one needs considerable domain-specific knowledge and skills to pose, represent, and solve problems within that domain. As researches point out, teachers should provide students the opportunity to integrate different thinking skills to solve a variety of problems. As acquiring higher order thinking skills has been widely recognized as one of the main objectives of science learning, science education looks for innovative strategies to develop these higher order-thinking skills and to make learning science more meaningful.

Our existing pedagogical practices in school are criticized for presenting content in lecture format to be memorized. Our school pedagogic practices, learning tasks and the texts we create for learners tend to focus on receptive feature of children (NCERT, 2005). Much teaching is still conducted by giving insufficient attention to learning strategies (UNESCO, 2003). The new focus is on the process of learning and providing environments and tools that encourage everyone to become successful and responsible learners.

In moving away from a deficit model of curriculum and towards independent learning, Information and Communication Technology (ICT) has substantive echoes of life long learning. Researches done by Roschelle, Pea, Hoadley, Gordin, and
Means (2001) revealed that computer technology can support learning and is especially useful in developing the higher order skills such as critical thinking by engaging students in authentic, complex tasks within collaborative contexts. There is a growing shift all over the world, from the use of technology as a delivery devise for school children to use of technology as a tool for exploration for knowledge and self-learning. A major pedagogic contribution of ICT is that it facilitates an alternative way of approaching differentiation. It becomes possible to define differentiation by learner choice, a process that is both dynamic and iterative.

ICT can provide access to huge range of resources that are of high quality and relevance to scientific learning. There are several researches which suggest online learning to be part of the traditional courses since it is found that online learning helps in improving learning, higher order thinking skills and learners’ motivation (Dabbagh & Kitsantas, 2005; Wingard, 2004; Fox & MacKeogh, 2003). However, science as a discipline demands certain kinds of learning experiences like experimentation, demonstration and all the topics cannot be transacted through online learning platforms. Therefore, the issue that arises here is not about the kind of learning resources or the mode of transfer but the proper blend of both online and traditional learning resources. Therefore, blended learning as a strategy for facilitating learning by rightly combining various components of traditional classroom learning and technology enhanced online learning is of paramount significance. Clark and Patrick (2005) conducted a study on blended learning in delivering science courses and found that students supported blended learning and it is possible to use online resources to deliver introductory science courses more flexibly without reducing the learning benefits. McCray (2000) reported the utility of online learning environment in traditional classes in a hybrid course both as an efficient means for executing activities previously associated with the classroom setting and as a means to allow the pursuit of higher levels of learning. These research findings are in support of the idea of blending face-to-face instruction and online learning.

Despite the recent advances of ICT in the field of education, there is little research into how online learning is actually being used in schools by blending with face-to-face instruction or how online learning platforms can be benefitted in science learning. Current researches suggest that the use of online learning platforms is in the developmental stage in all sectors, and is particularly nascent in many secondary schools, with this technology being used mainly to share information or as a
document repository. Several online learning platforms have been designed to improve learning approaches. However, research findings about their impacts on science learning, their scope of providing learning experiences by catering to the needs of students belonging to different learning styles etc, are less likely to be explored.

Relatively recent and emerging researches focus on blended learning, in different contexts. Even though several international studies have been conducted in the area of blended learning, most of them are in higher education and in industrial or business environment than in school-level teaching. Research review reveals that there is lack of studies in Indian educational context on blended learning strategy on science learning at school level. Researchers in India have hardly explored this area of research. In this context, it is critical to design a blended learning strategy and find its effect on higher order thinking and learning science at secondary school level.

5.4 THE PRESENT STUDY

Recent developments in science and technology have had a tremendous impact on our ways of living and on our outlook upon the world. Since Science is a way of looking at phenomena as well as factual information about such phenomena, the methods, approaches and strategies employed in science should provide situations in which children have opportunity to explore, to learn independently and to think logically. But too often, science-teaching over emphasizes narrow mastery of the conventional explanations and techniques of established science. With the advent of Information and Communication Technologies such as internet, students have access to widespread knowledge. Online learning gives students opportunities to collaborate with the world to internalize their experiences and acquire deeper meaning. In this context, it is important to properly blend online learning and face-to-face instruction to ensure or to optimize science learning and develop higher order thinking including critical thinking and problem solving. Considering this, an attempt is made to study effect of blended learning strategy on higher order thinking and learning science and the study is titled as “Effect of Blended Learning Strategy on Higher Order Thinking and Learning Science among Secondary School Students”.

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5.5 OPERATIONAL DEFINITIONS

**Blended Learning Strategy:** Blended learning strategy is a planned combination of face-to-face instruction and online learning. In the present study, blended learning refers to a pedagogical strategy to engage students in learning of science by blending face-to-face instruction (computer based instruction, lecturing, demonstration, discussion and experimentation) and online learning.

**Higher Order Thinking:** Higher order thinking is a mental process, which leads to higher levels of cognition such as critical thinking and problem solving.

**Critical Thinking:** Critical thinking is purposeful, self-regulatory judgment, which results in interpretation, analysis, evaluation, and inference as well as explanation. (American Philosophical Association, 1990). The present study defines critical thinking as a person’s ability to use the cognitive skills such as interpretation, analysis, evaluation, inference, explanation and self-regulation when problems/issues in science are presented.

**Problem Solving:** Problem solving is defined as a person’s cognitive ability to perform mental operations so as to achieve the goal of solving a problem.

   In the present study, problem solving refers to a person’s cognitive abilities involved in solving a problem such as comprehending the problem, clarifying the problem and finding solutions to the problem when problems/issues in science are presented.

   In the present study, cognitive abilities such as sensing a problem, defining a problem, analysis of problem into discrete elements, ability to discriminate between the most relevant and closely related concepts, using analogies for reasoning, using inductive/deductive reasoning, hypothesizing, checking the testability of hypothesis, controlling of variables, prediction, conceiving ideas using diagrammatic representation, conceiving a strategy to execute a plan of action to test the hypothesis, drawing inference from relevant observed data and generalizing are considered as subcomponents of problem solving.
Learning Science: Learning Science is defined as acquisition of facts, concepts, laws, theories and principles in science as well as proficiency in science process skills.

Science Process Skills: Science process skills refer to a set of intellectual skills that are essential for acquiring reliable information about nature. In the present study, science process skills refer to basic science process skills such as observing, comparing, classifying, quantifying, communicating and predicting.

Science Achievement: Science achievement refers to knowledge, understanding and application of scientific facts, concepts, laws, theories and principles pertaining to the selected content of ninth standard science curriculum.

Learning Style: Learning style refers to the characteristic ways (visual, auditory, kinesthetic) through which learners perceive, interact with and respond to their learning environment.

5.6 OBJECTIVES

1. To find the effect of blended learning strategy on students’
   a) Critical thinking
   b) Problem solving
   c) Science process skills
   d) Science achievement

2. To study the difference in
   a) Critical thinking
   b) Problem solving
   c) Science process skills
   d) Science achievement
   among experimental group students with different learning styles as an effect of blended learning strategy

3. To find the reaction of students towards blended learning strategy

4. To identify the difficulties faced by students while learning science through blended learning strategy
5.7 HYPOTHESES

1. Blended learning strategy is more effective than the conventional method of teaching in enhancing students’
   a) Critical thinking
   b) Problem solving
   c) Science process skills
   d) Science achievement

2. There is no difference in
   a) Critical thinking
   b) Problem solving
   c) Science process skills
   d) Science achievement

among visual, auditory and kinesthetic learners of the experimental group as an effect of blended learning strategy.

5.8 RESEARCH QUESTIONS

1. What are the reactions of students towards blended learning strategy?
2. What are the difficulties faced by students while learning science through blended learning strategy?

5.9 VARIABLES

The real science learning encompasses not only the acquisition of science facts, concepts and theories but also the development of process skills as well as higher order thinking among students. In the present study teaching strategy is taken as the independent variable wherein blended learning strategy is employed as the experimental intervention for teaching science. The dependent variables considered are critical thinking, problem solving, achievement in science and science process skills. Besides these, learning style is considered as a moderator variable.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Dependent Variable</th>
<th>Moderator variable</th>
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</thead>
<tbody>
<tr>
<td>Teaching Strategy</td>
<td>Critical Thinking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Problem Solving</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science Process Skills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science Achievement</td>
<td></td>
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<tr>
<td></td>
<td>Learning Style</td>
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</tbody>
</table>
5.10 SAMPLING PROCEDURE

Secondary school students were chosen as the population. Purposive sampling technique was employed in selecting the schools. Two CBSE affiliated schools were selected from Bangalore city for the study, one school having the provision of online learning platform ‘www.thinkquest.org’ and another school, without the online learning platform.

Balangadaranatha Swami [BGS] National Public School, Bangalore in which the online learning platform ‘www.thinkquest.org’ is available, was selected for the experimental intervention. The intact group of 38 ninth standard students of the school was regarded as the experimental group. The intact group of 36 ninth standard students of Jyothi Kendriya Vidyalaya, Bangalore was selected as the control group.

5.11 DESIGN OF THE STUDY

The study is quasi-experimental in nature wherein a pretest-posttest non-equivalent groups design was employed. Pretests were administered to both the experimental and control groups to assess critical thinking, problem solving, science process skills and science achievement. The experimental group was taught six chapters of science using blended learning strategy by the investigator whereas the control group was taught the same science chapters by regular teacher using the conventional teaching method. Then posttests were administered to both the groups.

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>Control Group</th>
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</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Pretest</td>
</tr>
<tr>
<td>Blended Learning Strategy</td>
<td>Conventional Method of Teaching</td>
</tr>
<tr>
<td>Posttest</td>
<td>Posttest</td>
</tr>
</tbody>
</table>

5.12 TOOLS

The study involved the assessment of critical thinking, problem solving, science process skills and science achievement of secondary school students. The following table presents the tests prepared and the dimensions/components/topics considered.
Table 5.1: Dimensions/Components/Topics of Tests

<table>
<thead>
<tr>
<th>Tests</th>
<th>Dimensions/Components/Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Thinking Test</td>
<td>Interpretation, Analysis, Evaluation, Inference, Explanation and Self regulation</td>
</tr>
<tr>
<td>Problem Solving Test</td>
<td>Comprehending the problem, Clarifying the problem and Finding solutions to the problem</td>
</tr>
<tr>
<td>Science Process Skill Test</td>
<td>Observing, Comparing, Classifying, Quantifying, Communicating and Predicting</td>
</tr>
<tr>
<td>Science Achievement Test</td>
<td>Matter in our surroundings, Is matter around us pure?, Force and laws of motion, Gravitation, Why do we fall ill?, Natural Resources</td>
</tr>
</tbody>
</table>

The steps suggested by Transler and North (as cited in Kishan, 2008), which are mentioned below were followed in the preparation and validation of the tests:
1. Survey of sub areas in the subject field
2. Preparation of test items
3. Critical evaluation of test items by experts
4. Formulating precise instructions for administration and preparation of scoring key
5. Tryout of the trial form
6. Item analysis to determine difficulty level and discriminative index
7. Establishing reliability of the test

Reliability coefficients of the tests are presented in the following table.

Table 5.2: Reliability Coefficients of Tests

<table>
<thead>
<tr>
<th>Tests</th>
<th>Reliability Coefficient (Cronback Alpha Coefficient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical thinking test</td>
<td>0.7</td>
</tr>
<tr>
<td>Problem solving test</td>
<td>0.73</td>
</tr>
<tr>
<td>Science process skills test</td>
<td>0.86</td>
</tr>
<tr>
<td>Science achievement test</td>
<td>0.87</td>
</tr>
</tbody>
</table>

The investigator also developed learning style inventory to determine the learning style of students – visual, auditory and kinesthetic. A reaction scale was
prepared to find the reaction of students towards blended learning strategy. The dimensions of the reaction scale adopted are ease of use for web environment, online environment, content, evaluation and learners’ views on blended learning in general. A semi-structured interview schedule was prepared to explore the difficulties faced by students while learning science through blended learning strategy.

5.13 DESIGN OF BLENDED LEARNING STRATEGY

A blended learning design suggested by Huang and Zhou (2005) is adapted for the present study. The procedure of designing blended learning strategy involves mainly three stages:

**Pre-Analysis:** It mainly consists of analysis of science curriculum, environmental features of the school and students’ characteristics. Ninth standard science curriculum was analyzed to understand the scope for implementing the blended learning strategy. Environmental features of the experimental school were analyzed through a preliminary visit to the school. Characteristics of ninth standard students including their views on online learning were collected and analyzed. The purpose of this task was to lay a sound foundation for organization of learning activities. Based on these, an analysis report was prepared.

**Activity and Resource Design:** The unique feature of blended learning design is that it focuses on which activities and resources are appropriate for the online learning contexts and which activities are appropriate for the classroom contexts. This stage mainly consists of two sub stages-

(i) **Overall design of blended learning:** At this stage, selected units were thoroughly analyzed by specifying concepts and their meaning and a comprehensive design of the strategy was worked out.

(ii) **Design of activities and development/selection of resources:** Suitable activities for transacting each topic were identified and detailed lesson plans were prepared. In addition to this, resources required for the effective implementation of the strategy were either selected or prepared.

**Instructional assessment**

Instructional assessment was based on the instructional objectives formulated and the activities carried out. It was mainly assessment of students’ worksheet, work
done online by analyzing articles published on students’ web pages and by analyzing their online interaction with others, examination of content knowledge through tests etc. In addition to this, students’ participation and interaction during face-to-face sessions were observed as part of the assessment of teaching learning process.

5.14 PROCEDURAL DETAILS OF THE STUDY

The present study was carried out in various stages. It includes pilot study and implementation which consists of administration of pretests, experimental intervention and administration of posttests, reaction scale and interview.

Stage 1: Pilot study

The intervention was tried out in BGS National Public School, Bangalore for a period of two weeks. It helped the researcher to identify the extent of online learning to be provided along with face-to-face instruction.

Stage 2: Implementation

- Administration of pretests and learning style inventory
- Experimental intervention
- Administration of posttests, reaction scale and Interview

5.15 EXPERIMENTAL INTERVENTION

The intervention was carried out for 69 Periods of 45 minutes each extending 20 weeks approximately. The time allocation for different types of teaching methods are given below.

<table>
<thead>
<tr>
<th>Teaching Learning Process</th>
<th>Number of periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiments</td>
<td>12</td>
</tr>
<tr>
<td>Project (Discussion, monitoring and feedback)</td>
<td>7</td>
</tr>
<tr>
<td>Lecture-cum-Demonstration</td>
<td>13</td>
</tr>
<tr>
<td>Computer Assisted Instruction</td>
<td>11</td>
</tr>
<tr>
<td>Lecturing</td>
<td>6</td>
</tr>
<tr>
<td>Online Learning</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69</strong></td>
</tr>
</tbody>
</table>
The experimental group was taught six units of science using blended learning strategy, which included both face-to-face instruction and online learning. Face-to-Face instruction included lecturing, discussion, demonstration and experimentation along with computer based instruction using CD-ROM. Online learning was facilitated using web based online learning platform ‘www.thinkquest.org’. Materials which were used in the classroom were made available on the online learning platform. Online learning was facilitated through options like publishing articles on web page, message board, list, uploading pictures, and video and through online collaborative projects with their peers as well as students of different countries. These activities were continued in the classroom with the guidance of the investigator. Activities done and discussions carried out in the classroom were continued through online learning platform. The researcher used the facility of interacting with students through message board and it helped the researcher to give timely feedback to the students. Online threaded discussions on various curricular issues were conducted. Meanwhile, lecturing, demonstrations and experiments were undertaken in the classroom as the content demanded. The discussion in the classroom was continued in the discussion forum using message board and vise versa. Students were asked to publish various write-ups on their own web page referring various websites prescribed by the researcher and by referring online library materials available on the online platform. Further discussion on the topics was continued during face-to-face instruction in the classroom.

5.16 CONVENTIONAL METHOD OF TEACHING

During the intervention period, the researcher visited the control group and observed science classes taken by the regular teacher. The discussions with the science teacher of the control group revealed that duration taken for teaching the selected units in the control group was approximately the same as that of the experimental group. Science classes were taken by the regular teacher using conventional teaching methods and were completely devoid of any kind of online learning. The control group visits revealed that topics were being taught through demonstration and lecturing, followed by answering questions from students. The interaction with the teacher and among students was limited and the bright students were answering questions whereas other students were mostly passive in the class. The interaction of researcher with students of the control group revealed that
experiments held were conducted in an isolated manner in the lab and were not as a continuation of the lecture/discussion held in the classroom.

5.17 ANALYSIS OF THE DATA

Both descriptive and inferential techniques were used during data analysis. Descriptive statistics such as mean, standard deviation, skewness and kurtosis of the scores obtained in pretests and posttests of both experimental and control group were used to ascertain normality of the distribution. Inferential statistical technique 2X2 ANCOVA (Analysis of Covariance) was used to find the difference in the adjusted mean scores of critical thinking, problem solving, science process skills and science achievement between experimental group and control group and to study the influence of learning style on these variables of experimental group students after being exposed to blended learning strategy. To analyze the reaction of students towards blended learning strategy, percentage was used. The analysis of data was carried out using SPSS (Statistical Package for Social Sciences). The responses of students about the difficulties faced while learning science through blended learning strategy were qualitatively analyzed.

5.18 MAJOR FINDINGS

1. Blended learning strategy is effective in developing critical thinking of secondary school students. Critical thinking of secondary school students was found to be improved after the intervention.

2. Blended learning strategy is effective in developing problem solving of secondary school students. Problem solving of secondary school students was found to be improved after the intervention.

3. Blended learning strategy is effective in developing science process skills of secondary school students. Science process skills of secondary school students were found to be improved after the intervention.

4. Blended learning strategy is effective in developing science achievement of secondary school students. Science achievement of secondary school students was found to be improved after the intervention.

5. It is found that there is no difference in critical thinking among visual, auditory and kinesthetic secondary school students as an effect of blended learning strategy; this means blended learning strategy was found to be
equally effective in improving critical thinking of experimental group students irrespective of their learning styles.

6. It is found that there is no difference in problem solving among visual, auditory and kinesthetic secondary school students as an effect of blended learning strategy; this means blended learning strategy was found to be equally effective in improving problem solving of experimental group students irrespective of their learning styles.

7. It is found that there is no difference in science process skills among visual, auditory and kinesthetic secondary school students as an effect of blended learning strategy; this means blended learning strategy was found to be equally effective in improving science process skills of experimental group students irrespective of their learning styles.

8. It is found that there is no difference in science achievement among visual, auditory and kinesthetic secondary school students as an effect of blended learning strategy; this means, blended learning strategy was found to be equally effective in improving science achievement of experimental group students irrespective of their learning styles.

9. It is found that secondary school students have an overall positive reaction towards blended learning strategy. Majority of students opined that the references and content provided meet their needs and contents in the web environment helps to learn the subject deeply. Most of the students responded that activities were useful, relevant to the topic and proper instructions were given for learning activities in the web environment. Majority of students find communication in the online forum to be sufficient in helping them reinforce the learning.

10. The major difficulties faced by secondary school students while learning science through blended learning strategy were lack of time, difficulty in accessing online platform and increased workload. Students felt that learning through blended learning strategy is very time consuming. They felt that time allotted for online learning in school was not sufficient and they have to get time for the online activities from the schedule at their house. Some of the students felt that interaction with other students through the platform was not sufficient. Students felt that feedback through the online platform was not immediate so they took more time to complete assignments.
5.19 DISCUSSION

The study was aimed at finding the effect of blended learning strategy on critical thinking, problem solving, science process skills and science achievement among secondary school students. The study was quasi-experimental in nature wherein a pretest-posttest non-equivalent groups design was employed. It was also attempted to study whether learning style has influence on these variables when the experimental group is exposed to blended learning strategy. The data was analyzed using descriptive and inferential statistical tools and techniques.

From the analysis and interpretation given in the preceding section, it is clear that blended learning strategy is effective in enhancing critical thinking, problem solving, science process skills and science achievement among secondary school students. Students of the experimental group with different learning styles don’t differ among themselves in these dependent variables as the effect of blended learning strategy. The results of the study are discussed and presented below.

5.19.1 Effect of Blended Learning Strategy on Critical Thinking among Secondary School Students

Analysis of the hypothesis showed that the experimental group which was exposed to blended learning strategy showed significant improvement in critical thinking compared to the control group which was taught through the conventional method. The result is indicated by the F value (F=10.219 and p<0.01). The finding of the study is in agreement with that of the result obtained by King (2002) that blended learning improves critical thinking and it also supports the findings of Ferdinand (2004) that self regulated learning which is a component of critical thinking was stimulated by blended learning and the result obtained by Yang (2002) that web based bulletin board discussion enhances critical thinking. The findings also corroborated with that of Krebs (2004) who studied the implementation of an online web design course at a suburban high school and found that students believed the online environment encouraged them to work at their own speed, to be active participants, to be intrinsically motivated and helped to individualize learning more than a traditional class. But the result is not in congruence with the findings of Lee (2004) that there is no difference in critical thinking between the online collaborative discussion group and the traditional individual assignment group. But in higher education sector, Flynn (2004) found that the practice of dialogic writing within online asynchronous
communities helps students to learn by allowing them to clarify their thoughts and test ideas. Hall (2005) found that in an online course, students tend to operate at the lower levels of critical thinking and only progress through higher levels when challenged to do so by the instructor. Yang (2002) found that using structured web based bulletin board discussions with Socratic questioning enhances students’ critical thinking in University and indicated that Socratic questioning helped students demonstrate critical thinking skills at a higher level.

These reviews correspond to the findings of the present study which suggests that by effectively blending online components, especially online discussion with face-to-face instruction wherein students are more challenged with more probing questions, critical thinking of students can be enhanced. The possible reason for the positive effect of blended learning strategy in fostering critical thinking is its learner centeredness wherein students are given opportunities to critically reflect, interpret, analyze and explain various phenomena and events in science by interacting with people both online and in face-to-face settings. In addition to this, by providing students opportunity to present their knowledge through a wide platform might have helped them to obtain diverse feedbacks from different parts of the world. This might have given more impetus to understand and reflect on their thinking and might have helped to develop self regulated thinking among students. The opportunity to learn through the sequentially arranged learning experiences during face-to-face instruction along with online learning might have helped the students to improve their abilities to infer, interpret, analyze and explain. Further discussion in the classroom followed by the online exercises or vice versa i.e. initial discussion in the classroom followed by online discussions might have helped the students to probe through the problem in depth, to think in different perspectives and to self regulate their learning. This is indicated by McKeachie, Pintrich, Lin and Smith, 1986 (as cited in Smitha, 2008) that instructions that stress student discussions enhances critical thinking.

It is further indicated by the findings of Dettori (2007) that blended learning supported self regulated learning and that of Dabbagh and Kitsantas (2005) that web-based pedagogical tools (WBPT) (e.g., collaborative and communication tools, content creation and delivery tools) supported different self regulated learning (SRL) processes (e.g., goal setting, self-monitoring). For example, in the present study, during the online project, collaboration with people of different countries and hands-on experiences obtained in surveys in their immediate locality might have
given opportunities for students to ‘think globally and act locally’. The thought provoking questions which were asked in the classroom as well as through the online forum might have helped students to probe the problem in detail and encouraged the students to think critically. Actively engaging students in project-based or collaborative activities can encourage students' critical thinking development if instructors model the thinking process, use effective questioning techniques, and guide students' critical thinking processes (Snyder & Snyder, 2008). The wider perspectives and insights obtained through these interactions might be another reason for the enhancement of critical thinking among students.

5.19.2 Effect of Blended Learning Strategy on Problem Solving among Secondary School Students

Analysis of the hypothesis showed that the experimental group which was exposed to blended learning strategy showed significant improvement in problem solving compared to the control group which was taught through the conventional method. The result is indicated by the F value (F=7.37 and p<0.01). The result of the study corroborated with those of other researchers like Case (2004) who showed that it is possible to improve problem solving strategies that students employ through the use of online collaborative learning activities. The finding of the study is in agreement with that of the result obtained by Lugo (2004) that multimedia computer technology is a potential supplemental teaching and has effect on problem solving skills of ninth through twelfth grade students with learning disabilities. The result of this study also corresponds to the findings of McLoughlin and Hollingworth (2000) that students' meta cognitive skills can be developed significantly by taking a proactive approach and by designing an environment specifically for problem solving. He asserted that meta cognition can be developed in contexts that engage students in self-monitoring their problem solving approaches, in scenarios where they can ultimately use that knowledge. The finding of the present study is in congruence with the findings of Lin (2003) who showed a high correlation between constructivist practices and problem-solving. But the result of the study is not in agreement with the findings of Bekele and Menchaca (2009) who examined the effects of blended learning on problem solving skills and found that there is no difference between experimental group and control group on problem solving. But the result of the present study is in congruence with
the findings of Lori and Warfield (1999) that co-operative learning strategy and problem solving teaching strategy improve problem solving of students.

The blended learning strategy attempted to open up various possibilities for students to explore problems through intuitive online questioning based on the evidences obtained from experimenting and by interacting online. It also provided chances to review their own strategies which are accelerated by immediate online feedback. This may be one of the possible reasons for the positive effect of blended learning strategy in fostering problem solving. Online interactions might have also helped students to self-correct and build upon each other’s ideas and thus making them feel that they are responsible for their own learning. These real life anchored instructions might have engrossed the elements of higher order thinking that leads the students to become effective problem solvers. The exploratory issues provided both on the online platform and in face-to-face setting might have helped the students identify the problems accurately and cognize deeply about them. The virtual environment blended with the instructions during face-to-face sessions also might have encouraged students to explore a topic beyond the boundaries of given materials. It might have supported the proactive and exploratory nature of learning and thus helped students to become better ‘problem solvers’.


Analysis of the hypothesis showed that the experimental group which was exposed to blended learning strategy showed significant improvement in science process skills compared to the control group which was taught through the conventional method. The result is indicated by the F value (F=17.213 and p<0.01). The result of the study is in tune with the result obtained by Tan, Yeo and Lim (2005) that computer supported collaborative learning enhances science process skills of secondary school students. The finding of the study is in congruence with that of Saat (2004) that web based learning environment helps students to acquire science process skills. This result is in agreement with that of the finding of Ferreira (2004) that multi sensorial activities and dialogue help children to develop science process skills. Hence one possible reason for the positive effect of blended learning might be the flexible classroom dynamics and learner centeredness with greater engagement by students. Students were provided with such learning experiences that actually triggered students
to ‘do science’. In addition to this, various multisensory activities such as demonstration, computer assisted instruction, experimentation, videos and simulations uploaded online and the online projects gave students opportunities to observe, classify, compare and infer. The different modes of activities which were sequenced appropriate to the content gave students opportunities to explore more about nature and resulted in the development of science process skills.

5.19.4 Effect of Blended Learning Strategy on Science Achievement among Secondary School Students

Analysis of the hypothesis showed that the experimental group which was exposed to blended learning strategy showed significant improvement in achievement in science compared to the control group which was taught through the conventional method. The result is indicated by the F value (F=16.632 and p<0.01). The result of the study is in tune with the result obtained by Moodley (2004) who studied the effects of computer-based dynamic visualization simulations on student learning in high school science and found that students’ understanding and performance were better in classes where teachers used the computer-based dynamic visualizations to complement their traditional teaching. The result of the present study is in agreement with that of Plough (2004) who analyzed students using visual thinking to learn science in a web based environment. He found that making visual sensations helped students understand science knowledge and making web pages helped students construct science knowledge structures. Since there are research findings (Sridevi, 2008) which indicate that the science process skills were significantly associated with the achievement levels of students, it can be inferred that the reasons for the improvement in science process skills can be implied to the similar results in science achievement. The most plausible reason may be the reinforcing effect of multiple modes of transaction catering to the individual learning style. It might have helped the students to understand the concepts clearly and the reflection of participants in online forums might have helped to acquire the scientific concepts and principles clearly.
5.19.5 Differential Effect of Blended Learning Strategy with respect to Learning Style

Analysis of the hypotheses shows that learning style has no influence on critical thinking, problem solving, science process skills and science achievement when students are exposed to blended learning strategy and the results are indicated by respective F values (F=0.094, F=0.005, F=2.764, F=1.074, p>0.05). This shows that students belonging to visual, auditory and kinesthetic learning styles are equally benefitted from the experimental intervention in the case of critical thinking, problem solving, science process skills and science achievement. These results are in tune with that of Benson (2005) who found that there were no significant differences in the final course grade with respect to learning style of students who are enrolled in a hybrid course. The result of the present study is substantiated by the findings of Wang (2004) that there were no significant differences in academic achievements with respect to learning style of students in an online learning environment. The result of the present study is in agreement with the findings of McCann (2005) that participants’ learning style had no statistically significant effect on their final posttest scores in both highly interactive and less interactive online learning environment and no significant interaction effect was found between the learning style and instructional method.

The learning needs of auditory, visual and kinesthetic learners might have been catered to by the learning inputs given through blended learning strategy as there were various modes of transactions like lecturing, demonstration, experiments, and instruction using video clips, PowerPoints, watching videos, conducting projects and online sharing. This means, the learners with different learning styles were equally benefitted by blending both the modes of transaction which in turn might have helped in developing critical thinking, problem solving, science process skills and science achievement irrespective of their learning style.

5.19.6 Reaction of Students towards Blended Learning Strategy

From the reactions of students with respect to different dimensions of blended learning strategy namely, ease of use for web environment, online environment, content, face-to-face instruction, evaluation and general reactions, it is clear that overall, students had a favorable reaction towards blended learning strategy. The findings of Buket and Meryem (2006) support the present study that students enjoyed taking part in the blended learning environment. The result is in agreement with the
findings of Strachota (2003) that student satisfaction is heightened in an online course. This is again in tune with the findings of Cottrell and Robinson (2003) that students prefer blended learning approach. But it contradicts with the findings of Prilluck (2004) who examined effect of two technologically different methods—traditional teaching and web-assisted method of instruction on student responses and found that students in the traditional course were more satisfied with their learning experiences. But the present study result is in tune with the findings of Clark and Patrick (2005) who found that delivery of science courses through blended learning approach were supported by students.

In the present study, students viewed positively the increased and improved communications and their responses are in tune with the result of Humbert and Vignare (2005) and of Riffell and Sibley (2003). The ease of getting readings online was appreciated by the participants in the present study. Majority of students find communication in the online forum sufficient as it helps to reinforce learning and provides access to lot of information. Buket and Meryem (2006) examined students’ views on blended learning environment and found that students enjoyed taking part in the blended learning environment. They asserted that face-to-face interaction had the highest score compared to other dimensions of blended learning. Similarly, students who participated in the present study also opined that they enjoyed learning through blended learning approach and they appreciated the relevance of activities conducted through face-to-face instruction. This demonstrates the importance of face-to-face interaction and communication for the success of blended learning.

5.19.7 Difficulties Faced by Students while Learning Science through Blended Learning Strategy

From students’ comments, it is evident that they feel learning through blended learning strategy is very time consuming. Many of the students opined that it is too time consuming in addition to their usual homework and studies. Similar findings were obtained in a study conducted by Bucy (2003) who identified cognitive load as the negative factor in learning through blended learning strategy. This suggests that optimal amount of work load should be maintained while designing blended learning strategy. Sufficient amount of time should be provided in the school for online activities as students of the present study opined that time for working online provided in the school was not sufficient. Some of the students feel that interaction
with other students was not sufficient and facilities like ‘brainstorming’ must have been used to ensure more interaction. Some of the students felt that feedback was not immediate and interaction was not sufficient. As discussed in the fourth chapter, it may be due to the lack of motivation of students to start an interaction with others by using the online facilities.

5.20 IMPLICATIONS OF THE STUDY

The present study was taken up in the context of blending online learning with face-to-face instruction in science learning. The findings of the research have several implications in the present educational system especially on initiatives in ICT integration in school education. The implications of the present study could be considered relevant for policy makers, curriculum planners, administrators, teachers and students.

The study presents a model of integrating online learning with face-to-face instruction in secondary schools. The study highlights positive effects of blended learning strategy over the conventional approach in fostering higher order thinking and learning science among secondary school students. Thus, the present research has implications on framing Government policies to improve quality of learning in general and science learning in specific. The study may initiate discussions in education sector for evolving new initiatives in pedagogical approach to enhance meta-cognition among learners and to empower students to become ‘Global Learners’. Having established that higher order thinking can be developed, serious efforts congruent with the present study may be undertaken to enhance critical thinking and problem solving among students through science education.

The positive reaction of students towards blended learning strategy suggests a way of making learning a joyful process and at the same time enhancing its quality. Since this strategy is more activity oriented, it is suggested that for effective implementation, the class strength should be limited in the range of 25-35. The study stresses the need to change the classroom environment for promoting higher order thinking and learning science by incorporating a collaborative learning atmosphere through a planned effort. This suggests that students need to be taught the social skills necessary for interacting with people especially through the online forums. Helping students learn to ask the right kind of questions and to build on each other’s thinking may be a key component in orchestrating collaboration.
Since the study revealed that students find time allotted for online learning in schools is not sufficient, this has an implication on school administrations to provide enough flexibility with respect to time and other resources so that the strategy can be effectively implemented. The study attempts to provide inputs to educationists in designing blended learning strategy for science learning. This could be used by educationists while designing similar educational programmes. Teachers may be given pre-service as well as in-service training in blending online learning with face-to-face instruction which will go a long way in effectively implementing the strategy.

The study examined ways and means of improving science education by blending online learning with face-to-face instruction by using the online platform made available by an NGO namely, ‘Oracle Educational Initiative’ working in schools. This indicates that initiatives by Non-Government Agencies and Public Private Partnership (PPP) can be entertained to improve quality of learning in schools.

5.21 DELIMITATIONS
1. The study was confined only to ninth standard students.
2. The intervention was carried out only for 6 units of ninth standard science.
3. Online learning activities included sharing information through message board and emails, online publishing of articles and uploading multimedia, online submission of assignments and online projects and excluded online activities such as synchronous online tutoring.

5.22 SUGGESTIONS FOR FURTHER RESEARCH
1. The study can be replicated with other populations including students at college level or primary level.
2. Studies can be undertaken with increased sample size and with more sophisticated experimental designs to arrive at even more dependable conclusions.
3. The present study of blended learning strategy is limited to science learning and therefore it can be extended to other disciplines.
4. A study could be undertaken by incorporating various other online components such as synchronous communication like instant messaging (chat), video conferencing etc.
5. The study can be extended to investigate the effect of blended learning strategy on other variables such as decision making, attitude towards science and social skills of students.

6. It might be educative to study the relationship between critical thinking and problem solving skill of students.

7. The study can be extended by considering affective dispositions of critical thinking along with its cognitive components.

8. It could be further investigated whether similar studies conducted over a longer period could produce better results.

9. A study could be undertaken to explore the challenges and constraints in the implementation of blended learning strategy.

10. A similar study can be undertaken by considering other learning styles such as Kolb’s learning styles.

5.23 CONCLUSION

The study was an attempt to find the effect of blended learning strategy on critical thinking, problem solving, science process skills and science achievement among secondary school students. The findings revealed that the blended learning strategy had a positive effect on critical thinking, problem solving, science process skills and science achievement of students. Learning style does not have influence on experimental group students’ critical thinking, problem solving, science process skills and science achievement after being exposed to blended learning strategy. To summarize, the study found that, by effectively blending online learning with face-to-face instruction, higher order thinking and science learning among secondary school students can be improved. Blended learning strategy can be considered as one of the new initiatives of pedagogical approaches for integrating ICT in science education.