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THEORETICAL OVERVIEW

The present study involved the development of a Computer Based Instructional Package in Physics at Higher Secondary level and testing its effectiveness over the existing Activity Oriented Method of Instruction by assessing the performance of students on the basis of the taxonomy of science education suggested by Mc Cormack and Yager (1989). Therefore the theoretical background of the study is organized mainly under two heads.

i. Computer Based Instruction

ii. Assessment Based on the Taxonomy of Science Education by Mc Cormack and Yager.

2.1 COMPUTER BASED INSTRUCTION

‘Computer’ literally means a tool or equipment or machine which computes or does calculations. It is a fast and accurate electronic symbol manipulating systems that is designed to accept and store input data, process them and produce output results under the directions of a stored programme of instruction.

Computer is the finest and most important gift of the science and technology to the mankind. It has done miracles in almost all walks of life. Today, there is no aspect of our life that remains untouched by the use and applications of computers. In the field of education too, computers are being used for managing its affairs including actual teaching.

_The functional use of a computer in education has been divided into three categories._

i. Management

ii. Instruction and Learning

iii. Educational Research

The management category includes school and classroom application in budgeting, accounting, record keeping, printed electronic communication and information retrieval. Instruction and learning has been sub-divided into teacher-centered instruction and student-centered instruction. The educational research category includes statistical analysis and information retrieval.
With the introduction of New Educational Policy in 1986, our Country also has taken initiative for making the use of computers in teaching learning activities. The instructional work so carried out with the help of computer is generally known as Computer Assisted Instruction (CAI).

Several terms or acronyms such as Computer Assisted Instruction (CAI), Computer Assisted Learning (CAL), Computer Based Instruction (CBI), and Computer Managed Instruction (CMI) etc. are used interchangeably to refer to the use of computer and related communication technologies in education. These terms are applicable in a wide sense to denote the use of computer technologies in the authoring of learning materials, their delivery, and the management of the educational process, training, instruction or learning. The subtle difference between the terms reflects the proportion of computer-support and traditional human activities in education and specifics of the computer based processes. In particular, “Computer based” typically pertains to situations in which technologies play a central role in the development and delivery of core instructional material and the performance of some management functions. “Computer-aided and Computer-assisted” pertain to instructional situations in which a computer plays a supplementary role in the development, delivery and storage of some of the learning materials but in general, the instructional process is human-oriented.

In the research literature, Computer Assisted Instruction (CAI) is a generic term that includes a range of forms, varying according to different implementations of computer technology to assist instruction. Hussain (2010) explained some of the more common terms that have been used in CAI related field over the years, which are mentioned in the following table.

Table 2.1

<table>
<thead>
<tr>
<th>CAI</th>
<th>Computer Assisted / Aided Instruction</th>
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<tr>
<td></td>
<td>The use of Computers in delivering instruction to students</td>
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<tr>
<th>CAL</th>
<th>Computer Assisted / Aided Learning</th>
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<td></td>
<td>The use of computers as educational aids, CAL is the interaction between a student and a computer system designed to help the student in learning. The CAL name is intended to emphasize “learning rather than just instruction”.</td>
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<td><strong>CTB</strong></td>
<td><strong>Computer Based Training</strong></td>
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<td></td>
<td>CAI with emphasis on its use as a training tool, usually in an industry environment.</td>
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<td></td>
<td>CBT is used to stress the performance – oriented character of the learning, i.e. it emphasizes the learner’s activities rather than the delivery of learning resources.</td>
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<th><strong>CMI</strong></th>
<th><strong>Computer Managed Instruction</strong></th>
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<td>The use of the computer to manage the file student’s progress or records.</td>
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<th><strong>CBE</strong></th>
<th><strong>Computer Based Education</strong></th>
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<td></td>
<td>CBE is the process by which written and visual information is presented in a logical sequence to a student by a computer. The computer serves as an audio-visual device. The students learn by reading the text materials or by observing the graphics. The primary advantage of the computer over other audio-visual devices is the automatic interaction and feedback that a computer can provide, multiple paths through which course materials can be taken, depending on the individual student’s progress.</td>
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<tr>
<th><strong>ICAI</strong></th>
<th><strong>Intelligent Computer Assisted / Aided Instruction</strong></th>
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<td>CAI / CBT that specifically contains audio, video or other non-textual information. Interactivity can range from a self-paced slide show to a fully interactive environment.</td>
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<th><strong>e-Learning</strong></th>
<th><strong>Internet Based Learning</strong></th>
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<td>CAI specifically aimed at use over a network or the internet.</td>
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<th><strong>IMPS</strong></th>
<th><strong>Instructional Management and Presentation System</strong></th>
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<td>A method to separate and simplify all levels and aspects of building CAI including both technical and instructional aspects.</td>
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<th><strong>LCI</strong></th>
<th><strong>Learner Controlled Instruction</strong></th>
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<td></td>
<td>LCI allows the learner to control the method or difficulty of instruction</td>
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<th><strong>SPIMM</strong></th>
<th><strong>Self Paced Interactive Multimedia</strong></th>
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<td></td>
<td>SPIMM is a collection of most of the features, such as – audio, video, animation, picture etc. that are to be included in an effective CAI.</td>
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### Theoretical Overview

<table>
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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>WBI</td>
<td>Web Based Instruction (CAI over the internet. Usually using html as a delivery method)</td>
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<tr>
<td>IMM</td>
<td>Interactive Multimedia (IMM) is defined as “a computerized database that allows users to access information in multiple forms including text. Graphics, video and audio”</td>
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<tr>
<td>TEE</td>
<td>Technology Enriched Education (Technology-enriched education reflects the facts that most of the learning materials make use of multimedia and the learning process involves interaction with the learning material rather than passive exposure to it)</td>
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<td>LTS</td>
<td>Learning Technology System (Learning technology systems comprise a wide range of tools, environments, courseware and resource management systems for educational purposes. Terms for specific kinds of LTSs belong to two groups: LTSs defined through their educational functions (intelligent tutoring system, learning environment) and LTSs defined through their technical features (nomadic learning technology system, distributed learning (technology system, web-based learning technology systems))</td>
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<tr>
<td>ITS</td>
<td>Intelligent Tutoring System (ITS pertains to a system designed to reproduce key features of a human teacher’s behavior. Usually, an ITS possesses knowledge about the domain, tutoring strategies and methods and is able to model the state of a learner’s knowledge)</td>
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<tr>
<td>LE</td>
<td>Learning Environment (Learning environments may be intended for unassisted learning experience or provide some help, coaching or guidance. They are designed to create conditions for effective learning and may include both digital and non-digital entities. A virtual learning environment may mimic a classroom setting by providing for typical activities such as presentation, discussion, exercising, testing etc. Small scale LEs may be based on simulations or games; another typical example of a LE is a virtual laboratory)</td>
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### Integrated Learning System

An integrated Learning System (ILS) is a far more specific term and such software can be differentiated from other computer delivered curriculum content in that it has additional components, namely an extensive record and management system. However, more recently, an ILS is seen as having the ability to present learners with a question, process the answer and then give feedback before selecting an appropriate subsequent question.

An ILS is a Computer – based system that manages the delivery of curriculum materials to pupils so that they are presented with individual programmes of work over a number of weeks and months. It has three main components to facilitate the management of learning by teachers.

**Curriculum Content:** This comprises an extensive range of tutorial, practice and assessment modules for a substantial part of a pupils’ curriculum with coverage across a range of curriculum subjects and levels of ability.

**A Pupil Record System:** This maintains information on every pupil and records pupil’s levels of achievement.

**A Management System:** This links and controls the flow of data may perform some or all of the following functions indicated by Brown (1977).

1. Interpretation of pupil responses in relation to the current task;
2. Updating of pupil records;
3. Choice of pathways through the curriculum content;
4. Delivery of the appropriate sequence of learning modules;
5. Provision of feedback to pupils and teachers (Brown, 1997, p.7)

### 2.1.1 Computer Assisted Instruction

Computer Assisted Instruction (CAI), as the name suggests, stands for the type of instruction aided or carried out with the help of a computer as a machine or simply it is the use of a computer to provide instruction. Splittergerber (1979) defined CAI as “A teaching process directly involving the computer in presentation of instructional
materials in an interactive mode to provide and control the individualized learning environment for each individual student”.

According to Chambers & Sprecher (1983), CAI is “The use of Computer to provide instruction (Course content) in the form of drill and practice, tutorials and simulations. The term is used synonymously with CBL (Computer Based Learning), CBI (Computer Based Instruction) and CAL (Computer Assisted Learning)”.

According to Batra (1989) “Computer Assisted Instruction (CAI) refers to a learning situation in which student interacts with (and is guided) a computer through a course of study aimed at achieving certain instructional goals”.

The use of computer has now almost revolutionized the field of instruction in all its dimensions. It can’t be defined now as a teaching device for presenting programmed instructional material and consequently, it will not be proper to define CAI as the type of instruction which makes use of computers.

The definition of CAI given by Bhatt and Sharma (1992) state that “CAI is an interaction between a student, a computer controlled display and a response entry device for the purpose of achieving educational outcomes”. This definition brings into light the following things.

- In CAI there is an interaction between an individual and the computer just as happens in the tutorial system between the teacher and an individual student.
- The computer is able to display the instructional material to the individual student.
- The individual student takes benefit of the displayed material and responds to it. These, responses are attended by the computer for deciding the future course of instruction displayed to the learner.
- The interaction between the individual learner and the computer device helps in the realization of the set instructional objectives.

### 2.1.2 Basic Assumptions of CAI

Computer Assisted Instruction is a method of instruction in which there is a purposeful interaction between a learner and the computer device (having useful instructional material as software) for helping the individual learner achieve the desired instructional objectives with his own pace and abilities at his command. It is meant for auto-individualized instruction and rests on the following basic assumptions.
1. **Instruction for a large number of learners at a time**

   Computer Assisted Instruction provides individualized instruction to a large number of learners, according to their abilities, and interest in a particular topic simultaneously. In CAI, the learner gets instructional material and help from the computer according to their needs. Hence, the first assumption of CAI lies in its capacity of providing quality and quantity auto-instruction to a sufficiently larger number of the individual learners at a time.

2. **Recording of Learner’s Performance**

   How the learner reacts to particular learning situations, the path followed by the learner in arriving conclusions, the time taken by the learner for completing the module, etc. can be accurately recorded by the computer device. It helps the teacher or programmer in further planning the needed instruction to the individual learner for the proper advancement. This timely and proper recording is the second assumption underlying CAI.

3. **Variety in the use of methods and techniques.**

   Every learner cannot be realized the objectives through a single method and all the subjects or topics cannot be handled through a common method or strategies. There should be a wide variety of methods and approaches for imparting instruction in a particular subject or topic so that all the individual learners get rich and varied experiences and may be able to choose a particular method or approach according to their own interest, ability and nature of the instructional material.

2.1.3 **Technologies of CAI**

   Computer Assisted Instruction requires a joint effort of various persons in the matter of wise handling of men and material resources. Generally it involves three types of technologies, namely hardware, software and courseware.

1. **Hardware**

   The computer as a machine represents the hardware. In CAI, we certainly need an appropriate computer to suit our teaching – learning situation. It will require the services of an expert or technician for its maintenance and operation. The teacher must have a workable knowledge of the working of a simple computer.
2. **Software**

The computer cannot do anything for imparting instruction to the learners if it is not fed with the software. The programmes containing instructions to the computer in a language that it can understand are called software. The programmes are developed by the experts called programmers. The software used in CAI is of two kinds: (i) application software, and (ii) system software. The application software includes instructions to the computer for carrying out a total function required by the user. The user’s concern is with this software. However, the system software is needed for organizing the resources of the computer to carry out the application tasks mentioned in the application programme. Its activities are: (i) to interpret the application programme in the code of the computer machine, (ii) to handle the input and output devices, and (iii) to schedule the work within the computer machine. Therefore, in a way, this software helps in the working of the computer or enabling it to do what is needed by the user in terms of its application.

3. **Courseware**

The courseware technology is the base of the instruction that is imparted to the learner by CAI. If a student wishes to learn a subject or topic through computer assisted instruction, the computer machine as a hardware will need the services of software – the application and system programmes for its operation. These programmes will be prepared by the software programmer, an expert in the software technology. But for its preparation, he will certainly require the services of those who are experts in courseware technology who include experts (i) in the subject (ii) in the methodology and strategies for teaching the subject, (iii) in instructional psychology and (iv) audio–visual aid preparation and use. What the courseware technology will prepare in terms of the instructional material and method of instruction, etc. will be translated by the software technologies into software programmes for being used in the computer machine.

In this way, these three technologies and the persons operating them are jointly responsible for the preparation of instructional activities conducted in CAI.
2.1.4 Modes of Instructional Software for Curriculum Integration

Computer assisted instruction can take a variety of forms for providing self individualized instruction to a learner depending on the computer services availed. Some of them are discussed below.

1. Computer Based Tutorials

The aim of teaching is to make the learning interesting simulating and effective. Traditionally this has occurred through the medium of text books, lectures, videos, audio – visual presentation etc. Computer based tutorials, if designed effectively, can deliver information, verify information and reinforce information through a process of interaction with the students. Tutorials are best used to present new information to students. In many instances, instruction is designed to be self-contained so that, the student can informed thoroughly regarding the skills or knowledge under discussion.

- The New Collins concise dictionary in English (1985) defines a tutorial as “a period of intensive tuition given by a tutor to an individual student or to a small group of students”.

- Real meaningful learning occurs when students attempt to start action what has been presented to them in the classroom to real cataloguing situation. Computer assisted learning packages based on the tutorial can be used to teach new content and it requires minimum assistance from the teacher.

- As the name indicates tutorial “tutor” the students. Its function is similar to that of a teacher or textbook in explaining information or concepts to learners.

- The best computerized tutorials employ the strategy called branching programmed instruction. The computer provides information in small segments
on the screen. Some of these segments prompt the learner for a response and accordingly computer’s next step takes place. This next step could be to

- give the learner a chance to try again.
- supply the learner next piece of information in the learning sequence, if the learner’s response showed that he / she was ready to go on.
- provide a remedial information to the learner through branching programme to permit review or explain the information in a different manner; or
- allow the learner to seek help by obtaining definitions clarification, or other information needed to solve a problem.

The course of action taken by the tutorial would depend on the nature of the learner’s response at each step.

In this type of CAI, the computers are engaged in actual teaching. Here they can play effectively the role of a tutor by maintaining a perfect interaction and dialogue with the individual students. The tutorial programmes are prepared not only to have instruction in certain topics but also to provide sufficient practice, having proper track of the student’s difficulties and performance and move the students on the path of progress according to their own pace, abilities and requirements. If the student has been able to master a concept, the CAI programme provides the next step of instruction, but if he is not able to achieve mastery, the programme provides remedial instruction.

2. Computer Based Drill and Practice

Much of what we learn requires reinforcement and practice before it automatically becomes part of the way we do things.

- Generally in the teaching or learning phase teacher introduces the concepts through activities related to real life situations, given feedback and when necessary have reinforced the concepts by drilling them with some other activities. This kind of teaching works very well.
- In computer aided, drill and practice, drills provide endless practice of clearly defined skills. The learner is given immediate feedback and when responses are wrong, corrective action is immediately instituted. The process can be repeated effortlessly until learner acquires mastery over that
skill. This repetitive process must be employed wisely and avoid the mindless repetition.

- Computer-based drills are used primarily for providing practice. Drill and practice exercises are “Supportive Activities” – they do not stand alone as an instructional scheme. Drill and practice is not designed to teach new information or skills rather, drill and practice is designed to reinforce previous training, knowledge or skills. Computer – based drills offer unlimited opportunities to practice concepts and skills that learners have already learned through other traditional methods.

- CAI provides the learner with different types of drill and practice programmes covering specific topics related to a particular subject. Through these, the services of computers can be properly availed for providing practice in something already learned in some other way. It helps in the development of a variety of skills.

- The advanced programmes on drill and practice select the problems of varying difficulty levels on the basis of the student’s performance during earlier sessions. The computer is known to have a good memory for the errors of the learners and, therefore, proves a very effective teacher in providing the students proper material for their drill and practice.

3. Computer Based Simulations

Certain useful educational activities cannot be done in the classroom because they may be too expensive, adventurous, time consuming, unethical or impractical due to some other reasons. The computer can help to simulate these activities in an inexpensive, safe, efficient, ethical and practical environment. Computer simulation for educational purposes is a part of computer- assisted learning.

Computer-based instructional simulations may be defined as the controlled representation of real world phenomena. These instructional methods are used when real world experiences are either unavailable or undesirable. Computer – based instructional simulation is among the most powerful educational delivery methods because computer- based instructional simulations provide situational, authentic form of practice, feedback about performances, ensures how a device or system can work effectively and motivates for learning while avoiding physical dangers and
constraints. In addition, simulation can use strategies that support student’s learning effectively.

According to Alessi and Trollip (1992), simulation is a powerful technique that teaches about some aspect of the world by imitating or replicating it. Students are not only motivated by simulations, but also learn by interacting with them in a manner similar to the way they would react in real situations.

Rothwell and Kozanas (1999) define a simulation as an “Artificial representation of real conditions”. According to Lee (1999), “A simulation is a computer programme in which it temporarily creates as set of things though the means of a programme and then relates them together through cause and effect relationships”.

Simulation differs from drill and practice or tutorial, as it provides learner structured activities. Simulation is used as a technique for providing training to the students. Such type of instructional activities provides powerful learning tools to them. With carefully prepared programmes, the students are made to face real or idealized situations. They have to play an active role and are required to take decisions that have consequences.

4. Computer Based Instructional Games

In computer based instructional games, the learners are provided with a variety of well – designed computer games. Games can be defined “as organized play”. It is a known fact that computer games engage people. Games as an instructional tool can be used as an environment to facilitate learning and acquisition of skills. They can effectively be used for the reinforcement of already taught skills, concepts and information (Hannafin & Peck, 1988). Games can also simulate a real situation but usually also provide some entertainment. The primary purpose in a game is, however the solving of a problem.

- Computer games can sometimes be regarded as an activity, which involves elements of “play”. These games should not be confused with academic type games. Their purpose is only to provide intellectual challenge, stimulation of curiosity and serve as a source of motivation to the individual learner. In a course of learning, these games can be used as a source of review or as a reward for some accomplishment for the learner.
Educational computer games are instructional activities that provide motivation, entertainment, completion and reinforcement while presenting a superficial or simulated reality. Computer games should motivate learners to enjoy a learning activity. Thus, an educational computer game is an activity in which participants follow prescribed rules that differ from those of reality as they strive to attain a challenging goal.

According to Grabe and Grabe (1996), care should be taken to ensure that all learners receive realistic reinforcement so that they do not associate technology only with pleasure but also express the belief that the playing of games should never be idealized.

As an educational tool, games are used to learn subject matter, data and concepts. The role of the computer during a game is to act as a competitor, judge and score-keeper.

Games may or may not simulate reality but their feature is to provide entertaining challenges. Instructional games normally incorporate some form of competition as a motivational component. The common denominator for instructional games is the capacity to provide practice in the application of skills, concepts and information, using a motivating competitive format. Instructional games tend to motivate learners and focus their attention on the goal of the game and these leads to efficient learning. Learning may be both incidental and intended. An effective instructional game maintains the student’s interest and encourages the acquisition and development of the desired knowledge and skills.

5. Computer Based Problem Solving

This type of computer-assisted instruction focuses on the process of finding an answer to a problem rather than the answer itself. Here, the students are provided with programmes that can make them think about the ways and means of solving the problem systematically. With the concrete ways suggested in the programmes the students can divide or analyze the problem into its small constituents and are able to device systematic procedure for its situation. Such programmes are useful for different types of students for increasing sophistication of their thought process helping them learn good thinking strategies and problem solving abilities.
6. **Computer Based Practical Work Oriented Instruction**

Computer-assisted instruction programmes can provide valuable help in supplementing laboratory and other practical work. A student can learn so many things about the science experiments before actually performing them in his practical class by watching and following a computer programme made for this purpose. Similarly, he can avail the necessary skills and experiences about practical tasks in other fields before actually engaging in such practical activities. Thus, the children will have a necessary preparation and background from computers for their better performances at the school hours.

7. **Computer Based Learning Affairs Managing Type**

In this type of instructional activities, the computer-assisted programmes provide valuable help in managing and supervising the learning affairs of the students. They can have a proper check over the learning activities of individual students by indentifying their academic weakness through extensive diagnostic testing and to prescribe educational programmes to meet their individual needs. They can give assignments, help in self study, library reading, and group work, take a test over assignments, keep progress chart and guide the teacher as well as parents to plan their children’s education. In the education of the differently abled children like deaf and dumb, the computers can provide the needed learning experiences with quite negligible efforts to the children. In this way, the computers can play a leading role not only in managing the affairs of the teaching – learning process but also in the whole range and areas connected with the world of education.

8. **Computer Based Informational Instruction**

It helps the learner get the desired information he needs. Here the computer can serve the role of an enquiry officer, to respond to the student’s enquiry with answer’s it has stored. It provides minimal interaction between the student and the computer programme. The sole purpose of this type of CAI is to provide essential information for the acquisition of concepts and skills. However, the individual learner can learn a lot by adopting an enquiry or discovery approach towards self – learning through such instruction.

2.1.5 **Computer and Individualized Instructions**

Computer is a generally employed in education as a facilitator, as an evaluator of student learning as well as a personal tool or ‘tool to think with’ for both students
and teachers. The objectives of universalisation of education cannot be achieved unless problems associated with regular classrooms are not overcome. In today’s setup it is very difficult task for a teacher to take care of each and every student in a heterogeneous classroom comprised of several types of individual differences among the students. It is impossible for a teacher to teach every individual according to their pace of learning and level of understanding in a limited time period. In brief, the limitations of the teacher in traditional classrooms are:

i. To provide teaching material according to the needs of each student.

ii. To teach every student according to his / her own pace of learning.

iii. To assess the learning of all individuals and keeping their record.

iv. To guide the students in view of their individual differences.

Individualized instruction emphasizes giving appropriate attention to each student and provides individualized instruction. Teachers can provide materials that meet different goals, employ different methods and have different content and levels of difficulty, so that students can work at their own pace. This means that students are at the centre of learning and teachers guide them and facilitate them to learn. It also acquires that students should take more responsibility for their learning. In individualized instruction, students are be evaluated on whatever they have learned. It is very different from traditional teaching and learning. In individualized instruction, it is necessary for a teacher to have mastery over various methods, techniques and materials for individualized instruction and to satisfy the need and interests of individual student.

2.1.6 Computers and Instructions

The greatest contribution of science and technology is the invention and development of computers and their uses in all sectors of human life. The computers have become more powerful, faster, cheaper, smaller, and easier to use and also become more convenient to borrow. Personal computers (PCs) are now within the reach of even ordinary people. In recent years, equipment such as hard disks, CD ROMs, laser disks, printers etc. used with computers are being developed of very low prices. Using these, a computer programme can handle sound, pictures and video along with text. Today “Multimedia” is a buzzword in the field of computers.
Computer networking such as Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN), and World Wide Web (WWW) etc. is another remarkable achievement in computer technology that can bring revolutions in education. As the hardware develops, computer displays become more realistic and cheaper. The computer with its virtually instantaneous response to students’ input, its extensive capacity to store and manipulate information and its unmatched ability to serve many individual students simultaneously is widely used in instruction. The computer has the ability to control and manage a wide variety of media and learning materials like films, filmstrips, video slides, audiotapes and printed information.

According to Taylor (1980) “a micro computer can be a tutor, tool or tutee”.

The role of ‘tutor’ is most familiar to teachers. The computer acts as a teaching assistant and delivers instruction to students. This application is called computer assisted instructions (CAI).

When the computer is used as a ‘tool’, it assists students in accomplishing some tasks. For example, a student might prepare his assignment on computer using a word processing programme.

The computer acts as ‘tutee’ when the student becomes the tutor and teaches something through developed programmes on computer with the help of a computer language.

Computers assist students and teachers in learning and instruction. It can be used in the management of information, which helps to administrators as well as to the office staff in maintaining and interpreting the records through computer applications. Hence computer acts as a tutor. Computers are versatile tool that can be
used for a variety of educational purpose. They offer several potential advantages as a medium of instruction.

2.1.7 Computer in the Classroom

The introduction of computer into the classroom needs first to train the teachers to control the learning process and to educate the students how to use computers and learn from the computer. The teaching – learning system involving the computer has three components – student, computer programmer and teacher. The important task is the communication between these three components of the system. The teacher thus provides the course material as well as the first criteria to analyze and judge the learner’s progress and accordingly control instructions at the learner’s console. The programmer develops the learning package accordingly. Computer understands the course material, which has to be stored and control instructions for its display at the student’s console. The interaction between computer and user (student) uses the decision rules stored in the computer to control the display of material and to analyze the learner’s response. Since the teacher is no longer directly interacting with student in the CAI environment, the designer of CAI courseware must develop a great insight in to the learning process in order to produce effective instructional programme.

2.1.8 Advantages of Computer Based Learning

1. Instructors are better equipped to capture the attention of the current generation of students who have grown up with television, videos and electronic games.
2. CAL provides a suitable alternative for lectures in response to the current trend of increased number of students and higher teacher / student ratios and the subsequent pressure resulting on the teachers.
3. CAL is a well suited offer to help in the area of remedial teaching because of its flexibility. That is, course modules incorporating varying levels of expertise, drill and practice exercises.
4. CAL allows the students to work at their own paces. Different students may have difficulty with different concepts. Fast learners can go ahead.
5. Students may concentrate on specific areas without holding up the rest of the group.
6. Small departments can benefit from CAL by reducing certain costs. For example, expensive laboratory experiments can be replaced by simulations and there may be less need to have human experts constantly available.

7. Use of Multimedia in CAL attracts even quite young students and captures the interest of reluctant learners.

8. CAL ensures a more consistent course delivery and eliminates the need to cope with different tutoring styles and personality clashes between teacher and student

9. Teachers are free to do other necessary work, hence increasing educational productivity.

10. Immediate feedback increases its effectiveness. Delayed feedback cannot be so effective because the student's knowledge retention diminishes as time progresses.

11. CAL is attractively flexible as students can learn as per convenience without the need of constant tutor guidance. They can skip sections covering topics which they already have sufficient knowledge.

12. CAL forces active participation of every student as it works on one-to-one basis.

13. When CAL is used to replace traditional teaching, its cost is justified due to high student usage and re-usability in various classes.

14. Integration of computers in subject curriculum helps to prepare the students for their subsequent careers by familiarizing them with information technology and PCs.

2.1.9 Teacher Roles in Computer Enriched Classrooms

1. Instructor

   When the computer is introduced into the classroom, an initial learning period occurs during which the children need time to become familiar and comfortable with the technology. At this time teacher needs to assume the most active role in instructing children, guiding them through new software and encouraging them for exploration of the material.

2. Coach

   As students gain experience with computers, the focal role held by the teacher gradually reduces; children are able to perform tasks independently and peers begin to
take over the role of instructor. The teacher then moves into the role of facilitator, providing guidance and support when needed and ensuring appropriate behaviors, while control of the situation remains in the hands of the child.

3. Model

Children will be much more likely to use the computer as a practical, integrated tool for learning if they see the teacher doing the same. Using the computer during whole and small group instruction and for recording stories and producing classroom signs and charts are ways in which the teacher can be a highly visible user of technology.

4. Critic

Responsibilities of the teacher in the computer – enriched classroom begin before the computer is introduced to the students. In providing a rich, challenging and appropriate learning environment, teachers must take an active role in selecting the software that will truly enhance children’s learning and development.

2.2 ASSESSMENT BASED ON THE TAXONOMY OF SCIENCE TEACHING BY MC CORMACK AND YAGER

In the broadest sense, a taxonomy defined in the field of education is a ‘classification system’ (Woolfolk, 1993). Taxonomies in education have focused mainly on evaluation and objectives (Bloom, Engethart, Furst, Hill & Krathwohl, 1956). Karthwohl et al., (1964) described taxonomy in the context of educational objectives as ‘A true taxonomy is a set of classifications which is ordered and arranged on the basis of a single principle or on the basis of a consistent set of principles. Such a true taxonomy may be tested by determining whether it is in agreement with empirical evidence and whether the way in which the classifications are ordered corresponds to a real order among the relevant Phenomena. The taxonomy must also be consistent with sound theoretical views available in the field. Finally a true taxonomy should be of value in pointing to Phenomena yet to be discovered (Karthwohl, et al., 1964).

The single most pervasive taxonomy in education is Bloom’s taxonomy (Bloom, et al., 1956). It was intended to help ‘teachers, administrators, professional specialists and research workers’ discuss and deal with ‘Curricular and evaluation problems’. The objectivity of the parts, the ability to organize behavior into categories
and the pyramiding structure of the hierarchy made Bloom’s cognitive domain taxonomy relevant to many different fields of education. Therefore it has greatly facilitated the development of educational curricula and evaluation devices. Over a period of time, the education community accepted Bloom’s taxonomy because the taxonomy had appropriate symbols, precise and usable definitions and consensus from the group that used it.

2.2.1 Taxonomies in Science Education

Only two explicit taxonomies are present in science education. They are the taxonomies put forward by Mc. Cormack and Yager (1989) and Neale and smith (1989).

Neale and smith (1989) constructed a configuration check list, or taxonomy for evaluating teaching performance. The feature of this check list included: lesson segment, content, teacher role, student role, activities or materials and management. The check list pertained to conceptual change teaching in science. A teaching performance was rated for each feature of the check list in terms of high vs low implementation.

Yager and Mc Cormack (1989) proposed that science had been viewed as a body of knowledge consisting of facts, figures, and theories, and this led to science instruction characterized by presentations of factual information. Yager and Mc Cormack believed that science education that stressed what they called the “knowing and understanding” domain limited students in developing the level of scientific literacy demanded by the needs of society and the world. They first proposed that science education might be viewed in the context of five domains but later expanded these to six domains when they included the nature of science.

The domains suggested by Mc Cormack and Yager are

1. Concept (knowledge) domain
2. Process domain
3. Application domain
4. Attitude domain
5. Creativity domain
6. Nature of science
Mc Cormack and Yager (1989) contended that too often, science education limited students to the first two domains that primarily focused on the process and product of science. They stated that other domains are also needed to be included more often in science instruction due to the increased focus on science, technology and social issues. Therefore an assessment framework for science teaching and experiences to promote science literacy should be organized around six domains as shown in figure.

Fig 2.1 The Domains of Science Education Suggested by Mc Cormack and Yager

Yager (1987) noted that what was typical of science tests were questions that assessed factual and recall type of knowledge. He emphasized and promoted assessment in all six domains. Table 2.2 - shows the foci of the six domains. If the domains are intended to support and anchor science, then instructions and experiences that provide learning opportunities in these areas are necessary for student understanding in science.
Table 2.2

*Domain Foci of each of Six Domains*

<table>
<thead>
<tr>
<th>Science Domain</th>
<th>Domain foci</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Concepts (knowing and understanding)</td>
<td>Scientific information – facts, concepts laws, hypotheses, and theories accepted by the scientific community</td>
</tr>
<tr>
<td>II. Process (exploring and discovering)</td>
<td>Process of science, how scientists work and think.</td>
</tr>
<tr>
<td>III. Application (using and Applying)</td>
<td>Application of what learned to do science, communications to everyday life; informed decision making.</td>
</tr>
<tr>
<td>IV. Attitudes (feeling and valuing)</td>
<td>Attitudes, sensitivity, social issues and impacts</td>
</tr>
<tr>
<td>V. Creativity (imagining and creating)</td>
<td>Idea generation, designing, problem solving.</td>
</tr>
<tr>
<td>VI. Nature of science (the scientific endeavor)</td>
<td>History and philosophy of science; how science progress and science knowledge and understanding develop.</td>
</tr>
</tbody>
</table>

1. **Conceptual Domain**

Science concepts are central to science instruction, and the student’s understanding of these concepts is crucial to successful teaching and learning. Millar (1989) noted that without an understanding of science concepts it would be nearly impossible for students to follow much of the public discussion of scientific results or public policy issues pertaining to science and technology. If a basic goal of science
education is to help students construct an understanding of the natural world, then student’s prior knowledge should be the starting point of instruction.

Assessment in this domain enters the field of view to help make determinations on where students are with respect to conceptual understanding. Students should have concrete experience with concepts before moving to abstraction, and they need opportunities to try and to do, not just to read about science. The evidence that science concepts have been learned can be seen most clearly when students can use concepts in a real world situation.

Science in the classroom has been viewed and practiced for decades as a body of knowledge or facts to be learned or absorbed by students. Classically this occurs via memorization of facts and concepts from a text book. Science facts are clearly important, but to memorize facts as if their acquisition is the sole purpose of science education violates the spirit and nature of science.

The concept domain includes facts, laws or principles, theories and the internalized knowledge held by students all fall under the umbrella of the concept domain (Yager & Mc Cormack, 1989). These are the currently accepted scientific constructs related to all of the sciences, and students may best learn these concepts through a curriculum that is conceptually sequenced for developing student understanding. Students must also experience the curriculum from conceptually sound models of assessment and instruction.

2. Process Domain

Science processes, often designated as inquiry skills, are embodied in the terms exploring and investigating. In science, the investigative processes require hands on and minds on activities, laboratory inquiries, and experiments that provide approaches for helping students understand scientific concepts. Students with experience in hands on activities could reliably note their own progress in laboratory activities.

The inquiry skills are necessary for dealing with everyday life and play a role in the development of an understanding of the natural world. The contexts in which the inquiries are set are important in helping students connect the inquiry skills to their personal experiences so that students do not see the processes used in doing science as entities used only in science.
The process domain includes the 13 process identified by the American Association for the advancement of science (1968) which provided the framework for the programme in Science: A process Approach. These are the generally accepted processes that scientist use as they accomplish their work and slight variations in how these are categorized do exist. The abilities to use these process skills can be the target for instruction and assessment. The process skills used in science are

a. Observing
b. Using space and time relationships
c. Classifying, grouping and organizing
d. Using numbers and quantifying
e. Measuring
f. Communicating
g. Inferring
h. Predicting
i. Identifying and controlling variables
j. Interpreting data
k. Formulating hypotheses
l. Defining operationally
m. Experimenting

These skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists. Process skills that the students use and develop in science courses are the same as those used by scientist at work. These are the tools they need to understand the workings of the world. The development of these process skills allows students to solve problems, think critically, make decisions, find answers, and satisfy their curiosity. The following skills and processes are central to the presentation of all content and the delivery of instruction and assessment activities in class rooms. SAPA grouped process skills in to two types - basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. These skills are listed and described below.
(a) Basic Science Process Skills

**Observing** – It is using the senses to gather information about an object or event. Observing involves obtaining information about objects, situations, or events using as many senses as possible. Observations may be qualitative or quantitative in nature. Observing provides both a basis for new inferences or hypotheses and a tool for testing existing inferences and hypotheses.

**Inferring** – It is making an “educated guess” about an object or event based on previously gathered data or information. Inferring means suggesting more about a set of conditions than is observed. Inferences are based on observed data and past experience. Inferences may evolve from both direct and indirect evidence and are modified on the basis of new evidence.

**Measuring** – It is using both standard and nonstandard measures and estimates to describe the dimensions of an object or event. Observations are quantified using non-standard and then standard units. Length, area, volume, mass, time intervals and force are among the measurements used. Appropriate measurement instruments and units within the metric system are selected.

**Communicating** – It is using words or graphic symbols to describe an action, object or event. Communicating is the process of organizing and processing data that occurs between the observation stage and the interpretation or generalization stage. It usually involves organizing “rough” data in a more compact and meaningful way (ordering, rearranging, comparing), depicting the data pictorially or graphically, and processing it mathematically (finding slopes, tangents) to facilitate interpretations.

**Classifying** – it is grouping or ordering objects or events into categories based on properties or criteria. Classifying involves grouping objects, concepts, or events on the basis of observable properties to show similarities, differences, and inter relationships.

**Predicting** – it is stating the outcome of a future event based on a pattern of evidence. A forecast is made about future events on the basis of ordered data. Predictions on the basis of ordered data, extrapolation beyond observed patterns of events, and tests of predictions can be made.
(b) Integrated Science Process Skills

Controlling variables – It is the ability to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Controlling variables involves the process of deciding which variables of factors will influence the outcome of an experiment, situation, or event, and deliberately controlling all recognized variables in a systematic manner.

Defining operationally – It is stating how to measure a variable in an experiment. It is creating a definition by describing what is done and observed. It is in the language of the students. Definitions are in context of students’ experiences – not from the glossary, not to be memorized.

Formulating hypotheses – It is stating expected outcome of an experiment. Hypothesizing is an “educated guess” made about an expected relationship between two variables in an attempt to explain a cause – and – effect relationship. Hypotheses are based on observations or inferences about a set of events. A hypothesis should be testable.

Interpreting data – It is organizing data and drawing conclusions from it. Interpreting is the process by which sense is made of the observations in the form of inferences, generalization, or explanation. It is usually a direct response to the problem under investigation and therefore includes judgments about the interpretation to fit with proposed hypotheses, and the limitation of the new knowledge.

Experimenting – An experimenting is a series of observations carried out under special conditions. Experimenting is the ability to conduct an experiment, including asking an appropriate questions, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a “fair” experiment, conducting the experiment, and interpreting the results of the experiment.

Formulating models – It is creating a mental or physical model of a process or event. This process involves the use of physical or mental models to describe the behavior of something that is unfamiliar. Constant vigilance is necessary to ascertain the validity (fit) of the model or analogy to the phenomenon modelled. Models often need revision to accommodate new facts.
(c) **Competency Indicators of Process Skills**

In order to identify the attainment of each process skill, indicators of process skills are useful. The competency indicators spell out what children should be able to do to achieve mastery of the process. Each indicator is one of many behavioral examples, which may be used to assess student competency. The descriptions below of each skill consist of a list of actions, which anyone involved, in using the process skill may be carrying out. The items in each list are not in any particular order.

**Observing**

- Observing objects or events in a variety of ways using one or more of the senses.
- Noticing relevant details of the object and its surroundings.
- Identifying similarities and differences.
- Discerning the order in which events take place.
- Using aids to the senses for study of details.
- Identifying properties of an object, i.e., shape, color, size, and texture.
- Using indirect methods, i.e., hand lenses, microscopes, thermometers, to observe objects and events.
- Observing objects or events by counting, comparing, estimating, and measuring.

**Inferring**

- Suggesting explanation for events based on observations.
- Distinguishing between an observation and an inference.

**Measuring**

- Comparing and ordering objects by length, area, weight, volume, etc.
- Measuring properties of objects or events by using standardized units of measure.
- Measuring volume, mass, weight, temperature, area, length, and time, using appropriate units and appropriate measuring instruments.
Communicating

- Talking, listening or writing to sort out ideas and clarify meaning
- Making notes of observations in the course of an investigation
- Constructing and using written reports, diagrams, graphs, or charts to transmit information learned from Science experiences.
- Choosing an appropriate means of communication so that it is understandable to others
- Using secondary sources of information
- Verbally asking questions about, discuss, explain, or report observations.
- After an investigation, reporting the questions tested, the experimental design used, results, and conclusions drawn, using tables and graphs where appropriate.

Classifying

- Identifying properties useful for classifying objects
- Grouping objects by their properties or similarities and differences.
- Constructing and using classification systems.

Predicting

- Forecasting a future event based on prior experience, i.e., observations, inferences, or experiments.

Using space / time relations

- Describing an object’s position i.e., above, below, beside, etc., in relation to other objects.
- Describing the motion, direction, spatial arrangement, symmetry, and shape of an object compared to another object.

Controlling variables

- Identifying the manipulated (independent) variable, responding (depended) variable and variables held constant in an experiment.
- Controlling the variable in an investigation.
Defining operationally

- Stating definitions of objects or events in terms of what the object is doing or what is occurring in the event.
- Stating definitions of objects or events based on observable characteristics.

Formulating hypotheses

- Suggesting an explanation which is consistent with the evidence
- Suggesting an explanation which is consistent with some scientific principle or concept
- Applying previous knowledge in attempting an explanation
- Realizing that there can be more than one possible explanation of an event or phenomenon
- Realizing the tentative nature of any explanation
- Identifying questions or statements which can and cannot be tested.
- Designing statements, i.e., questions, inferences and predictions which can be tested by an experiment.

Interpreting data and drawing conclusion

- Putting various pieces of information together to make some statement of their combined meaning
- Finding patterns or trends in observation or results of investigation
- Identifying an association between one variable and another
- Making sure that a pattern or association is checked against all the data
- Showing caution in making assumptions about the general applicability of a conclusion
- Organizing and stating in his / her own words information derived from a Science investigation
- Revising interpretations of data based on new information or revised data.

Experimenting

- Designing an investigation to test a hypothesis.
Theoretical Overview

- Conducting simple experiments.
- Recognizing limitation of methods and tools used in experiments, i.e. experimental error.
- Utilizing safe procedures while conducting investigations.

Formulating models
- Creating a mental, physical, or mental verbal representation of an idea, object, or event.
- Using models to describe and explain interrelationships of ideas, objects, or events.

Planning investigations (including prediction)
- Making use of evidence from past or present experience in stating what may happen
- Explicitly using pattern in evidence to extrapolate or interpolate
- Deciding which variable is to be changed (independent) and which are to be kept the same (controlled)
- Carrying out the manipulation of variable so that the investigation is ‘fair’
- Identifying which variable is to be measured or compared (dependent variable)
- Making measurements or comparison of the dependent variable using appropriate instruments
- Working with an appropriate degree of precision

(d) Hierarchy of Science Process Skills

Science process skills are unlimited. The above list is just a few common process skills. There are so many other process skills as well. But these process skills cannot exist in vacuum. They are interrelated and interdependent. Integrated process skills can be achieved only after the attainment of basic process skills and hence Science process skills can be arranged in a hierarchic order. Rezba et al., (1995) presented the Science process skill hierarchy as given in figure 2.2.
Figure 2.2 Hierarchies of Science Process Skills

In the figure, basic process skills are indicated by bold letters and integrated process skills by normal letters.

From the figure, it is clear that the foundation of all process skills is the process skill, observing. As the diagram indicates, the development of one process skill in the hierarchy depends on the formation of other skills.

3. Application Domain

A key element in the application domain is the determination of the extent to which students can transfer and effectively use what they have learned to a new situation, especially one in their own daily lives (Gronlund, 1993). Students must demonstrate that they not only grasp the meaning of the information and processes but that they can also make applications to concrete situations that are new to them. The application domain is important because it involves students using concepts and
processes not only in a familiar context but in addressing new problems. Students who can apply what they have learned to new situations provide evidence that they have an understanding of a concept.

Two major arenas where students use applications are in school and in daily life. In school, application often involves problem solving or learning new material by using knowledge and skills acquired in previous studies. In daily life, the crucial factor appears to the ability to choose the concepts and skills pertinent and relevant for dealing with novel situations. An issue based approach to science learning can serve as a vehicle for engaging students in learning that is local, personal and relevant.

**Attributes of the Application Domain**

The attributes of the Application Domain are given below.

- Use of critical thinking
- Use of open ended questions
- Use of scientific processes in solving problems that occur in daily life
- Abilities to make interdisciplinary connections – integration of the sciences
- Abilities to make interdisciplinary connections – integration of science with other subjects
- Decision making related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than on hearsay or emotions.
- Understanding and evaluation of mass media reports on scientific developments
- Application of science concepts and skills to technological problems
- Understanding of scientific and technological principles involved in common technological device.

4. **Attitude Domain**

Attitude is very broadly used in discussing issues in science education and is often used in various contexts. Two general categories that are distinguishable are

(a) Attitude towards science which is characterized by interest in science, attitude towards scientist and attitude towards science etc.
(b) Scientific attitude which is characterized by open-mindedness, honesty or skepticism etc.

Interest in science tends to decline as students experience more science classes and progress through school. Science educators need to work to retain student interest in science and need to consider changing both instruction and assessment practices to be more students centered in order to promote ongoing interest.

The positive attitude may enhance student’s effort to seek answers for their own problems and lessen their reliance on others. Students should be able solve problems with greater independence without parent or teacher intervention. The end result of this self-directed growth could very well be self acceptance and responsibility for lifelong learning.

**Attitude Domain Attributes**

The attitude domain calls for experiences that support

- Exploration of human emotion
- Expression of personal feeling in constructive ways
- Decision making about personal values
- Decision making about social and environmental issues
- Development of more positive student attitudes towards science in general
- Development of positive attitude towards oneself (an “I can do it” attitude), and
- Development of sensitivity to and respect for the feelings of other people.

**5. Creativity Domain**

Torrance (1978) defined creativity as the process of becoming sensitivity to problems, deficiencies, gaps in knowledge, missing elements and disharmonies. He also described it as the identification of the difficulties, the search for solutions, making guess or formulating hypotheses about the deficiencies. The testing and retesting of the hypotheses, possibly modifying and retesting them, and finally communicating the result all relate to and rely on the creative process. Creativity is integral to science and the scientific process.

Creativity plays an integral role in the many processes of science and doing science. Scientific creativity is defined by Moravesik (1981) as “Scientific creativity
may be viewed as the attainment of new and novel steps in realizing the objectives of science. Creativity is a complex construct. It is difficult to assess and rests very often in what might be called recognizing it when you set it. If a science educator wishes to foster a classroom that enhances student’s creativity, the classroom should probably become more students centered. Creativity is fostered and nurtured via richness in experiences. Creativity calls for openness in the classroom, acceptance of ideas, thinking outside of the box, a try new thing approach, and so called go with the flow approach.

Studies have suggested that the work done in the laboratory rests on the ability to manipulate the objects and the instruments used. There features of laboratory practice make the need for creative abilities paramount. First, scientists and students do not work with the natural world as it is; rather, they manipulate the objects of study to make them more accessible for experimentation. Second, investigator do not work with the natural world where it is but are instead able to bring those natural objects in to an artificial or vicarious setting. (e.g.: the laboratory, the classroom). Third scientists and students do not need to study an event only when it happens but, rather, can cause the event to occur unnaturally when the situation demands it (Knnor - cetina, 1981). These three characteristic of a laboratory require an imaginative, inventive mind capable of performing these investigations. These aspects of scientific enterprise are often ignored in the traditional classroom. Yet they are integrated to science instruction.

Scientific experience that can push the creative domain are likely to have some of the followings attributes.

**Creative Domain Attributes**

The creative domains calls for experience that promote

- Visualization – production of mental images.
- Generation of metaphors
- Divergent thinking
- Imagination
- Novelty –combined objects and ideas in new ways
- Open ended questioning
- Solving problems and puzzles
• Consideration of alternate view points
• Designing devices and machines
• Generation of unusual ideas
• Multiple modes of communicating results and
• Representation in various ways and modes.

6. Nature of Science Domain

The endeavors undertaken by researchers in their attempts to understand the natural world can promote student’s understanding of how science progresses. Science is a human endeavor that relies on reasoning, insight, energy, skill and creativity (NRC, 1996). Honesty, values, open mindedness and what Benchmarks for science literacy (AA AS, 1993) denotes as habits of mind all play roles in scientific ways of knowing. Working with science teachers to develop their understanding of the nature of science is recommended so that they can provide instruction that promotes their student’s understanding of this construct.

In the course of human history people have developed many interconnected and subsequently validated ideas about the physical, biological psychological and social worlds (AAAS, 1990). Successive generation enabled by these ideas, have achieved more comprehensive and reliable understanding of the human species and the environment. These ideas have been developed through particular ways of observation, thought, experimentation, and validation. These ways are the bases of what is meant by the nature of science and they are reflective of how science differs from the other ways of knowing (AAAS, 1990).

How scientific knowledge has developed and the roles scientists have played during the processes are two fundamental aspects that are important for students to know. Raising student awareness and developing an understanding of these expects should be included in science learning. Science is dynamic and many ideas in science have come and eventually been replaced or discarded. This tentative nature of scientific knowledge should be emphasized in science classroom.

The scientific knowledge is tentative has two facts that should be expressed explicitly when working with students. First the purpose of science is to develop a systematic knowledge in order to understand how nature behaves. Students should see science as a human endeavor in which scientific knowledge is developed by humans.
in an attempt to make sense of the world. Accordingly, scientific knowledge is not a truth to be discovered in the natural world but rather a man made explanation. Scientific knowledge can be changed, shifted from one point of view to another, due to external social influences such as politics, economics and culture (Kuhn, 1962). This suggests that scientific knowledge is not absolutely objective. Therefore, the understanding of the involvement of social factors in scientific development provides another focus for science education.

Science, accompanied by the power of technology has unique characteristics that affect society. The potential of science to do good is very often offset by the power to cause harm, and long-term outcomes and effects are not always predictable.

An important aspect of the nature of science is related to how scientists think and work in the scientific community. Helping students to understand more of the nature of science can promote deeper understanding of what it means to do science. Many people view scientists as a group of people who are more objective and intelligent than others. Students often believe that scientists can solve problems merely based on their scientific knowledge. Science however is a human activity that engages real people.

In doing science, scientists often work collaboratively, and given the specializations in science and related areas, a team approach is very often needed to work on problems. Peer review is an important component of doing science, and scientists expect to be challenged and to defend the work they have done. The work that scientists do must be replicable so that others can verify the work.

Science instruction in the classroom should attempt to portray the nature of the discipline. Teaching only for the retention of facts without grounding them in real world experiences well, sooner or later, only result in the loss of these facts from memory. In an attempt to reflect the nature of science, group work, reporting findings, discussion and reaching consensus are all parameters involved with the nature of science domain.

The Nature of Science Attributes

The nature of science domain calls for experiences that address

- The framing of questions for scientific research
• The competitive side of scientific research
• The methodologies used in scientific research
• The interactions among science, technology, economy, politics, history, sociology and philosophy
• The ways in which teams cooperate in scientific research
• The history of scientific ideas, and the ways in which science builds understanding of the natural world.

2.2.2 Assessment Approaches Aligned with the Six Domains

Assessment approach should include multiple measures of what students know and can do as a result of their learning experiences. The use of multifaceted assessment approach has the potential to provide a better profile of student understanding in the six domains.