CONCEPTUALIZING ABSTRACT CHEMICAL
CONCEPTS WITH LEVEL OF THOUGHT
AT SECONDARY SCHOOL LEVEL
IN PAKISTAN

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FOUNDATION UNIVERSITY COLLEGE
OF LIBERAL ARTS AND SCIENCES
RAWALPINDI-PAKISTAN

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By

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Reg.No.160/FUCLAS/PhD.Edu-2009

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education at Foundation University College of Liberal Arts and Sciences, Rawalpindi

FOUNDATION UNIVERSITY COLLEGE OF LIBERAL ARTS AND SCIENCES RAWALPINDI-PAKISTAN

2011
DEDICATION

This thesis is dedicated to my parents, who have been a source of immense energy and a symbol of great resilience against the odds I came across in my life.
FORWARDING SHEET

This thesis entitled “Conceptualizing abstract chemical concepts with level of thought at secondary school level in Pakistan” submitted by Sarfraz Ahmed in partial fulfillment of the requirement, for the degree of Doctor of Philosophy in Education, under my guidance and supervision, is forwarded for further necessary action.

Dr. Mohammad Tayyab Alam
Supervisor
This thesis entitled “Conceptualizing abstract chemical concepts with level of thought at secondary school level in Pakistan” submitted by Sarfraz Ahmed in partial fulfillment of the requirement, for the Degree of Doctor of Philosophy in Education, is hereby accepted.

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(Dr. Iqbal Shah) Supervisor

External Examiner Prof. Dr. Maqsud Alam Bukhari  
(Dr. Zaigham Qadeer) Principal/Dean

FUCLAS
AUTHOR’S DECLARATION

Except where otherwise acknowledged in the text, this thesis represents the original research of the author. The material contained herein has not been submitted either whole or in part, for a degree at this or any other university.

Sarfraz Ahmed
ACKNOWLEDGEMENTS

All the praises and appreciations are for Omnipotent and Almighty Allah who is the Creator and the Teacher of each and every being. All respects and blessings are for the Holy Prophet (PBUH) who opened the doors of knowledge for humanity.

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Sarfraz Ahmed
ABSTRACT

This study was undertaken to investigate the effectiveness of two instructional methods (i.e. Johnstone’s three-cycle instructional method and traditional instructional method) in the teaching of chemistry. Johnstone conceptualized that if chemistry concepts are made distinct and represented at three levels, are helpful in the meaningful learning. The main objectives of the study were to compare the relative effectiveness of these two instructional methods on the student learning and achievement. This experiment was carried out for the period of twenty two weeks in the chemistry classroom and laboratory of Federal Government Boys Model School F-8/3 Islamabad. Seventy-six science students of class ninth were randomly selected for the experiment. The design conceptualized for the study was the “posttest –only equivalent group design”. The research study had two groups i.e. experimental and control. Both the groups were equalized on the basis of eighth class science achievement scores. Different tools used to collect data were; multitier formative tools and a summative achievement tool. Experimental group was taught through Johnstone’s instructional method and the control group was taught through the traditional instructional method. Formative assessment was also made by the formative assessment tools. The achievement of the students in the chemistry theory and practical was measured by the summative tests called posttest theory and posttest practical. During the study the traditional formative assessments were also administered. The instruments constructed were validated. Data collected were analyzed and given the shape of mean scores.
In order to compare the mean scores of the experimental and the control group, $t$-test was applied. The analysis of the data revealed that Johnstone’s instructional method was more effective than the traditional instructional method because the experimental group performed significantly better than the control group. Important information revealed was that the traditional measures of assessment were not suitable for the assessment of meaningful learning. Qualitative assessment mode was suitable for meaningful learning because these are not meant for the assessment of rote learning. The study demanded that learning and the way of assessment need to be matched. The study emphasized that the examination system of Pakistan needs to be re-evaluated and Johnstone’s instructional method be applied in chemistry classrooms in Pakistan and laboratories need to be improved for effective learning of chemistry.
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CHAPTER 1

INTRODUCTION

1.1 Background of the Problem

Education has been shaping and constructing societies and shouldering their socio-economic uplift. The strengths and weaknesses of any society are the result of their education. Education is a multifarious process and has a leading role in not only changing the society specifically but also the social makeup. Most of the educators have argued in a similar vein and with the same sense of urgency about the social mission of education. Education has to prepare youth for living in an ever changing society. Our world is instantaneously changing and knowledge is continuously in a state of explosion. Education is a very important change agent which can change not only individuals but also the entire social structure. To do this we need quality education. It is a universal precept that the quality education is quality teaching and quality learning. The important aim of quality education can only be achieved by understanding the nature of the learners i.e. the way they learn and reforming the instructional methods and revisiting the existing role of laboratory.

National Research Council (NRC, 2006) claims that interest in science education is a worldwide phenomenon and it is shared by industrialized as well as developing countries. It is further indicated that an important and crucial factor that can contribute to the overall scientific progress is effective science education. It means that the dream of socio-scientific progress can not be realized without effective science education. Science education and science are basic and fundamental part of our curriculum. The significance of science is two folds i.e.it frames the thinking and
makes it critical. Science education being the core area of education system, it acts as a common thread to combine the core concepts that are the part of our natural environment. When science education combines and unifies the concepts, it is helpful in controlling the natural phenomena and uses these for the benefit of mankind. Furthermore, science education is entirely a human endeavor and needs more human efforts for its sustainability and productivity to the maximum.

According to Anderson (1983) the earlier goals of science education are no longer ample and vibrant and needs to revamp. He further stressed that the world has changed and it is continuously changing. The schools need to be responsive to the changing frontiers of the society. The new goals are developed for science teaching to take care of the personal and social needs of the students.

Science educators view science education works as an interface between science and society and bridges up the two i.e. Science and society. Yager (1984) recognized the multifaceted role of science education i.e. science education is of mutual and reciprocal in nature. First of all science education studies the mutual impacts of science on society and in turn the actions of society on science. Good et al. (1985) went forward and claimed that science education research should address and identify (i) the learning difficulties of the learners and (ii) help them learn science. He further stated that science education should help the learners to understand science. Kromhout and Good (1983) recognized a very important characteristic of science education that the ideas of science education constitute its body as a body are well organized and are coherent in nature. The ideas of science education are well interwoven and form a well structured whole. This character also lies at the soul of scientific method. So science education is well rooted in scientific method.
The quality of life owes to scientific and technological advancement and progress. The quality of life is at the heart of science and technology. Science directs us and helps us to figure out and decipher the natural and physical phenomena i.e. the physical world. It results in a body of knowledge which is aligned with observation, experimentation and prediction. Science is also a way of thinking that promotes an attitude of objectivity, self examination, and a search for evidence. Technology on the other hand, is applied science, not science. It translates scientific knowledge to benefit human race. Technology as a body of knowledge also aims to improve to the quality of life (Chiappetta and Collette, 1989).

“Science technology and society” (STS) is contextual in nature and builds relationship between science and society and is also a prime source of relevance. It links well the content, context and teaching learning strategies. Scientific technological and the basic concerns of society enable students to be familiarized with a problem, investigate the problem, collect and process the data, infer sensible and workable choices from the gathered data and make knowledgeable decisions.

“Science technology and society” (STS) is a rich source of knowledge and has the ability to familiarize and provide students with a wide array of important and essential abilities and competencies that are close to their daily life and have practical utility for their routine life (Rubba, 1987).

Regarding the central focus of science education, some science educators (Yager, 1983, 1984, 1985; Hofstein and Yager, 1982) argue that science courses should revolve around science technology and society i.e. STS. Zoller and Watson (1974) were also the proponents of the STS inclusion. While some science educators such as (Kromhout & Good, 1983; Good et al. 1985) advocated that science should be taken as a research discipline.
Experimentation lies at the heart of science education. The students should be well versed and knowledgeable with the structure and methods of science (Kromhout & Good, 1983; Good et al. 1985). But Bybee (1987) has another point of view. She argues that “science technology and society” should be a subset of science education instead of having a separate entity.

According to National Science Teachers Association (NSTA, 1982) the central concern of science education is to ensure the active participation of students in the scientific activities, problems, questions and scientific enterprise. To achieve this prime objective, science education has to concentrate and devise the ways to improve the student’s mode of thinking and the ways they probe their surroundings and the environment around them. Science education aims at preparing and developing scientific literates. This critical and crucial objective of preparing and developing scientifically and technologically literates can only be achieved by understanding, the way science sees the problems and the way it intends to solve these problems. This vital attribute of science needs to be translated into instruction.

Bybee (1997) thinks that scientific literacy is a vehicle to achieve what society wants and develop individual understanding about the way science sees the problems and finds the solution to these problems i.e. the basic constitution and feature of scientific and technological knowledge. In a present-day society, the success of life is highly dependent on advanced scientific and technological knowledge and it is essential to grapple the intricacies of this modern world. Up-to-date scientific and technological knowledge creates vigilance for the current life. Besides the basic and lowest level of literacy i.e. reading and writing, simple computational skills, full participation in the present and future society is a basic requirement. The knowledge of scientific concepts and their applications ensures the
success and participation of the present day individual in this real world. The person lacking the knowledge of scientific concepts needs to be made scientifically literate to such an extent that his full and active participation and contribution in this modern society is assured. Outmoded ways of acquiring knowledge and instruction can not succeed to achieve the general goal of scientific literacy. Therefore meaningful ways of knowing and instruction is a critical prerequisite to solve the problem of scientific literacy and enabling the people to solve the routine problems with the help of scientific concepts and principles.

The problem of developing critical thinking can be solved by improving (i) ways to learn and making it meaningful endeavor (ii) practicing and opting for variants of teaching methods which facilitate and contribute to productive teaching and learning (iii) developing scientific concepts and principles that are central to the secondary level science education. In spite of all these basic intentions science education is a rich source of scientific concepts and how these scientific concepts can be learned by the students. Science education has to arrange and manage the conditions and situations that lead to the better understanding and comprehension of these scientific and technological concepts and the world around them. At secondary level, science education aims at nurturing the critical and rational thinking. This significant aim of development and improvement of critical and rational thinking can be achieved by the experiences which provide the students with opportunities to think critically and rationally. Effective teaching methods help to develop scientific concepts, which facilitate the understanding of the physical environment and the world around.

Effective classroom teaching in science requires advance thinking and proper planning. Certain points like objectives, content, methods, teaching aids, evaluation
techniques are required to achieve desired outcomes. World Book Encyclopedia (1970) views teaching as face to face, one to one and is helping process in which one is guided and facilitated by the other. Teaching is not mere a direction that is received by the learner. The learner is facilitated in order to gain knowledge, competencies and attitudes. An exemplary teacher guides the learner instead of directing him/her. The guidance underlies the principle of learning by doing and motivates the learner to do activities and learning experiences that help to achieve the objective of learning with understanding. In nutshell, it can be summarized that teaching sets the stage for learning and creates such situations that are contributing to learning. Master teachers on their own analyze and evaluate the teaching learning situations to identify the situations that are more contributory to learning and enhance the ability to understand concepts. The teaching itself is a scientific inquiry. The teacher has to follow the fundamentals of the scientific inquiry while teaching. The other important domain of teaching is assessment. While engaged in assessment, the teacher acts as a researcher and his activities are similar to scientific inquiry. The teacher performs the dual job (i) conducts researches in order to modify the current teaching practices and making these more meaningful by varied meaningful assessment formats. The teacher is an action researcher. He identifies the problems that hurdle teaching learning process. To achieve this noble objective the teachers plan alternative assessments that collect evidences that are helpful to evaluate the current teaching practices, suggest modifications and enrich the ways to learn.

Alton-Lee (2003) and Hattie (2002) believe that student achievement is largely an outcome of good teaching. Similarly, Hill (2000) also believes that school’s culture and good teaching practices are of vital importance for student’s achievement. It
means that it is the need of the hour to make teaching good in all respects and good teaching is a basic requirement for meaningful learning.

Kwon (1991) noted a very significant role that the science teacher has to play in the classrooms. It (i) facilitates student learning scientific knowledge through problem solving skills and scientific methods and (ii) to discourage students to memorize scientific facts. Therefore, pre-service science teacher needs to develop his/her abilities to practice problem solving skills in their classrooms.

Arends (2004) unveiled that modern and successful life demands relevant and quality educational programs. A teacher is an important vehicle and change agent who deliberately brings about behavioral changes in the learners and provides them the learning experiences which are relevant to their life situations. In schools the teachers influence the attitude and interests of the students by encouraging and motivating. They also develop the abilities by providing the knowledge of useful scientific realities, scientific concepts, knowledge of procedures and getting the control of own learning and about the world.

According to NRC (1996) the teachers continuously and ceaselessly collect data regarding the way students learn and the factors that affect their understanding of the scientific concepts. In the view of the data collected they make necessary changes and amend their ongoing teaching learning process. The necessary amendments are strictly rooted in their interpretations of scientific inquiries to provide opportunities to the students to learn better. The teachers make critical observations at classroom level; hypothesize the possible causes that affect the teaching learning process. The teachers also involve the students when they are testing their conjectures to bring about the alterations in the teaching learning process.
Productive pedagogies have been a matter of concern in the area of productive pedagogies. Teachers need to be supported timely and appropriately in the professional learning (Stoll, Fink and Earl, 2003).

According to NRC (1996) the major concern of science education is to improve the teaching and learning. The capable and competent teachers create environment and situation in which they and their students work and participate in an active manner. The teachers ensure their activeness; participation and learning by doing. The teachers continuously struggle to expand not only the scientific knowledge but also the knowledge of learning and teaching. To achieve science teaching standards the teachers need to be provided necessary resources such as appropriate time to prepare and teach appropriate number of students per teacher, and work according to well thought schedules.

NRC (2000) visualized that scientific inquiry, as a mode of teaching, can only be implemented effectively if the teachers are adept in the basic scientific concepts, laws and principles. They must understand the real essence and spirit of inquiry not only as a method of teaching but also as a method of learning. The science content means the basic scientific concepts, laws and principles. They also need to be knowledgeable about the working of these laws and principles and the way the concepts are linked together.

NRC (1996) envisaged that factors such as appropriate time, space, and physical facilities are significant components that contribute to an effective science teaching and provide learning environment that promotes the sustainability of effective inquiry and understanding. The promotion of science education can not be realized unless helpful conditions and situations are not generated. Therefore the building of situations that promote scientific knowledge is a common human
endeavor and is a collaborative activity. Teachers design the ways for efficient use of resources.

While discussing the nature of the teaching Anderson and Burns (1989) asserted that teaching is neither passive nor one way process but it is highly interpersonal, interactive and it involves verbal exchange of ideas and is intended to help and facilitate the learners while they are learning.

Teaching is an amalgam of science and art because it aims at providing the conditions for effective learning. It is also synthesis in nature, can not act in isolation. Both are targeted at development of the human mind’s overall capabilities i.e. rational and innate. Both science and art are necessary, supplementary and complementary in nature and provide basis to visualize the nature of teaching and learning.

Multitudes of researches on learning science have shown that the students have certain existing ideas about science, and its nature, and the way. (Driver, 1983; Osborne, 1986).

It is well understood and confirmed that language has a significant and key role in teaching and learning. The problem of unfamiliar language on the potential of learning of science was conceived by Cassels and Johnstone (1978, 1980, 1983, and 1985). The scientific terminology and scientific jargon particularly pose a problem of unfamiliarity. Some words are often changed in an unfamiliar way. There are some fundamental psychological factors which affect the learner’s ability to learn in an unknown medium. There lies a chance of underperformance of foreign pupils than the natives (Cassels & Johnstone, 1983).

Language affects learning and this effect is particularly the product of one’s lack of knowledge of sentence structure and the language rules. Language is totally contextual and those who are given language experience in their early developmental
stages take hold of it easily and develop their chunking ability (Klatzky, 1980). Poor knowledge of syntactical rules places the bilinguals at a disadvantage and they fail to attach the words with their meanings (Johnstone, et al. 2001).

The other side of the coin is that the second language poses psychological threats and hinders the information flow in the minds of the learners. When the learners fail to find meaning in the text and anchorage in the long-term memory and then go for rote learning, a worthless effort fails to develop chain and link up the two types of information. The reason for opting the rote learning is the non-availability of attachment points for the incoming information that is presented to the learners.

The alignment between science content and language is highly demanded. The scientific concepts and the use of language are quite inseparable and both assist each other. Their interdependence is highly recognized (Huang and Morgan, 2003). The scientific concepts can not be grasped until the meaning of the word is understood. Therefore concept formation is favored if the meaning of the words are grasped actively and meaningfully. Therefore understanding the meaning of words is necessary for learning of concepts. As language supports learning, therefore language of the subject communication and its effects must be critically analyzed so that the learner successfully achieves the overall learning objectives. (Buchanan and Helman, 1997; Dong, 2002; Fang, 2006; Staples and Heselden (2002). They further pointed out the technical nature of the language of science and prescribed the ways to improve the learning of science through language i.e. group work and activities involving conversation and mutual interaction. If scientific concepts are brought under discussion the learning is enhanced. Team work and group discussions have also been recognized as important and essential tools in the field of learning of scientific concepts (Case, 2002). Hard words are difficult in nature and hinder the learning
because these are a major source of unfamiliarity. There is utter need to make hard
and difficult words little easier. Nation (1995) contradicted the meaning-focused
strategy and suspected the reliability of this effort because it heavily depends on the
excellence of learner’s reading expertise and control. The hard words are stumbling
blocks in the way to learn. Therefore keeping in view the wordy difficulties that the
learners face, it is bitterly recognized and a common consensus to make these difficult
words a little easier for students struggling with scientific vocabulary and subject
specific content.

There are certain factors that affect the information flow. Information
Processing Model was devised by Johnstone (1993). The information processing
theory intends to bring into line the situations that contribute to learning and the way
students learn and the process that leads to a better achievement.

*Figure 1.1  Information Processing Model of Johnstone*

![Information Processing Model of Johnstone](image)

Adapted from Johnstone, (1993)

When new subject matter and content is presented, the learner selects some of
this according to the ideas that are already present in the form of memory. Here the
notion of familiarity is in action. The stimuli that correspond and relate to the senses
easily find the way through the senses. There is great demand of alignment between
sensory filter and the memory storage. The information that is interesting easily filters through the perception filter which is purely differential in nature. Direct proportion exists between incoming stimuli and the perception filter. However the level of familiarity is also controlled and highly dependent on the information already held within the long-term memory. Operationally the sensory filter is partially controlled by the long-term or permanent memory. The filtered material enters an area which is the thinking part which gives sense, logic and meaning to the entered information. It is the way the material or information is prepared for storage. Johnstone (1999) conceptualized that the said model is really a mechanism for learning. It is also supportive in nature and helps the learners in devising the ways to organize the information in the permanent memory in an efficient and effective manner.

There are some simple predictions from the model.

- Inverse proportion occurs between working memory overload and learning.
- If the perception filter is efficient, the working memory load will decrease.
- The filtration which means separation of desired and undesired information is controlled by the long-term memory or the knowledge already stored (Reid, 2007).

Johnstone model predicts the way humans’ process new information. It also predicts the ways of improvement in the learning and how information can be chained and related to the information present in the permanent memory. The model also foresees that inconsistent learning situations may cause problems in the ongoing teaching and learning. The learning situation needs to be in line with the information processing style of learners. The contributory effect of model has been recognized in improving learning as a whole i.e. learning within the laboratory and learning by problem solving (Reid, 2008).
Reid (2007) sees meaningful learning as matching and linking of previous knowledge and the new knowledge. Ausubel (1968) highly stressed the importance of previous knowledge and conceptualized the feedback loop and its influence on the perception filter. The importance of links has also been reported and recognized by Al-Qasmi (2006). There should be alignment between the incoming information and the ideas already held in the permanent memory. Concept understanding is the result and outcome of the meaningful pattern and linkage of ideas (Danili and Reid, 2006; Hindal, 2007). Similarly (Reid and Yang, 2002a, 2002b) asserted that information recovery and upturn from the long term memory is highly hooked on the manner the information is stored.

The theory of constructivism places the learner in an active state. The knowledge constructed in the mind has variants. The thing to be noted is that all learning of knowledge is not created equal. Learning is on a continuum between memorization learning and purposeful learning. Meaningless learning ensues when new information is simply memorized without making connections to prior knowledge or when there is no prior knowledge available for making connections to the new information. Ausubel et al. (1968) clearly distinguished meaningless learning and meaningful learning. The figure clearly depicts what Ausubel et al. (1968) conceptualized. Building on earlier knowledge has also been recommended by (Thomas, 2004; Watts and Truscott, 2000).

One perspective about learning is that the vigor of learning lies in activity and dynamism. In reality, it is an active process in which the learner is fully engaged in the learning situation and manipulates with the environment. On the other hand learning is also viewed as a social process in which the learner is active and actively constructs new knowledge cooperatively and collaboratively. Instruction is viewed as
a process of supporting and facilitating the ongoing process knowledge building, rather than communicating and conveying knowledge (Brooks and Brooks, 1993). There is logic of knowledge building i.e. the earlier concepts help in the assimilation of later and the new concepts are formed and again the reorganization of the earlier and later concepts takes place. (Fosnot, 1992). Purposeful learning is the outcome when learners are put in the learning situations and learning experiences. This notion has been verified and recommended by Duffy and Cunningham. (1996)

*Figure 1.2*  Reception-discovery and meaningful-rote learning continuum

Meaningful learning has three requirements.

- Firstly, the learner must obtain some relevant prior knowledge in order to incorporate the new knowledge.
- Secondly, the material to be learned must be meaningful. It means that it must contain important concepts and propositions relatable to existing knowledge.
- The final requirement for meaningful learning is that the student must make a conscious and deliberate decision to learn meaningfully i.e. ready to incorporate this meaningful material into his/her existing knowledge (Bretz, 2001; Ausubel, 1968; Novak, 1998). A concept map of these requirements for meaningful learning is shown in Figure 1.3.
While teaching chemistry we look into its nature. Johnstone (1991) conceptualized that the concepts of chemistry according to their nature can be given three forms or levels. These three levels of concepts of chemistry are represented in the form of a triangle. Each corner of this triangle is called level of thoughts, concepts or idea’s representation. It can be further elaborated that the ideas/concepts of chemistry are found in three forms and if instruction is supported by this triangle, the learning is likely to grow. The superiority of any corner can not be claimed but each one is complementary in nature. The scrupulous linking of the corners is of high demand. The distinction of the concepts of chemistry is:
a) The macro and the touchable i.e. sensible, perceptible having touchable materials in nature what can be sensed.

b) The sub-micro: microscopic in size that can not be sensed through normal vision e.g. micro parts of matter i.e. untouchable and non-perceptible in nature.

c) The representational or figurative form: concepts of chemistry expressed in signs, formulae, equations, molarity, mathematical operations and graphs.

Figure 1.4 shows the diagrammatic representation of the levels visualized by Johnstone.

Figure 1.4 Three aspects of representation in the physical sciences

Macro and easily observable concepts

Sub-micro

Symbolic and mathematical

microscopic concepts

Adapted from Johnstone (1991)

Johnstone (1982, 1991) said that major hurdle in the way to understand chemistry is symbolic and sub-micro level and are root causes of many misconceptions in chemistry. Both the levels are abstract in nature and need to be made concrete. The microscopic and the symbolic concepts are used as vehicle to understand and conceptualize the concepts of macro nature. These are interactive in nature and have to be manipulated skillfully and with expertise. Thus chemistry
teachers, in order to increase the learning and instruction, need to be supported by
some images and illustrious resources that make microscopic concepts visible and
observable and present these to students so that they may develop mental models of
the molecular world.

Nahum et al. (2004) pointed out that the students frequently encounter the
macroscopic world of matter but they fail to establish a link between chemistry and
their surroundings and they also feel difficulty to move between the levels of matter

NRC (1996) also recognized that the chemistry concepts must be given three
forms, or levels particularly in grades 9 to 12, to ensure the inter-conceptual and intra-
conceptual meaningful movement. These conceptual movements develop the
understanding of how matter behaves at three levels. The instructional process has to
arrange, manage the ways that facilitate these movements. The instruction has to
remove the hurdles that may hamper the learning of chemistry concepts.

Bojovic and Sisovic (2000) concluded that fragmented, non-linked and non-
structured knowledge be short of the links and relations between concepts. The
learners get struck and their inter-conceptual and intra-conceptual movement is
greatly disturbed. They further reported that learning with understanding of chemical
concepts require thinking at three different distinct levels i.e. (a) large scale i.e.
macroscopic, (b) small scale i.e. microscopic, and (c) representational, symbolic or
sign chemistry. They also identified the significant the role and the need to develop
the cause-effect relations i.e. how macro concepts help to understand the micro and
vice versa. One concept beautifully interprets and explains the other and helps the
concept formation.
Gilbert and Treagust (2008) found that one major concern of chemistry education is to teach well, the connections between phenomenological world and the world of particles, atoms and subatomic units. They stressed the need to connect adequately the ways we represent chemistry. From their point of view, connecting macro to sub-micro link in a comprehensible way is one of the most demanding tasks for secondary school teachers.

According to Gabel et al. (1987) the explanation, understanding and interpretation of chemical phenomena call for the understanding of micro concepts. They further argued that the microscopic level was represented in the elementary and secondary textbooks. For that purpose, the teachers should be familiar with the concept to understand their everyday observations and the concepts taught to the students. Hence these concepts need to be included in their pre-service basic skills course.

Mostly the students find chemistry difficult and have low achievement (Carter & Brickhouse, 1989). Chemistry as a discipline deals with the properties and reactions of substances and the substances are usually conceptualized as aggregations of particles. The chemical and physical properties of these substances are linked to the nature of bonding, these substances possess. The particles and the bonding, present in these substances has has abstract nature. Due to its nonconcrete and nonpresentational nature, the students feel it unpleasant and beyond the senses (Nahum et al. 2004). Carter & Brickhouse (1989) claimed that the difficulty, the students feel, is context based. The abstract concepts have been taught traditionally without keeping in view the information processing capacities of the students and without differentiating the concepts of chemistry into three forms. It means that the difficulty the students face while learning chemistry concepts lies in their abstractness.
Gabel (1996) identified that chemistry is a complex and difficult subject and this nature of chemistry has implications for the contemporary teaching of chemistry. Gabel maintained that the complexity and the difficulty of chemistry solely lies in the way the chemical concepts are taught. Gabel (1996) claimed that teachers traditionally, unconsciously move from one level to another and do not help students to elaborate these levels. They move across and integrate these levels. It is very important to make distinction between these representations of matter. The unconscious working with levels may result in confusions rather than understanding. It implies that the teaching and learning demands of chemistry concepts are differential. Simultaneous introduction of concepts also poses threat to not only teaching but also to learning. It also implies that time should be allocated for different concepts. Can the traditional ways of teaching solve this complex problem? The learners feel chemistry difficult and unpleasant because they are being taught traditionally without making chemistry concepts distinct.

Johnstone (1999, 2000) stated that traditional teaching method has been in practice since long in spite of all demerits and shortcomings. According to Zarotiadou and Tsaparlis (1999) the traditional method of teaching is a common issue in the science education literature because it draws on student inactiveness and does not involve the learners. Traditional teaching methods have a number of variants and alternatives such as oral (explanatory, instructive) and formal i.e. teacher actively delivering the information to the inactive students. They further identified that when the students are in the concrete learning stage they are active learners i.e. they actively manipulate with their environment and actively interact with real and physical objects and then learn abstract ideas. The ideas that have non presentational nature are difficult to be sensed and at the same time difficult to learn. This difficulty of the
learners can be solved by making use of the principle “learning by doing”. When the learners engage they learn.

Piaget (1964) viewed that cognitive development is produced when the child works actively with the environment and the difference may arise between the information present in the permanent memory or the knowledge possessed by the learner and the new information i.e. thought conflicts. The thought conflict that is the outcome of environmental interaction of the child leads to self-regulation. Similarly Johnstone (1999) deals with the nature of chemistry and suggested to deal it as per its nature otherwise rote learning may invoke.

Kempa and Diaz (1990a, 1990b) made a very valuable analysis and concluded that all teaching methods are situational and their usefulness is highly dependent on the ways students learn and they gave emphasis to structure the teaching learning process as per se. So efficacy of the teaching methods can be enhanced by using these according to the situations. The superiority of any teaching method can not be claimed. Some researches found expository, teacher-centered instructional strategies superior to active student-centered methods (Ray, 1961; Hines et al.1985). Kletzy (1980) compared the effectiveness of an innovative experimental method and traditional lecture method following Piaget’s theory to teach the abstract and theoretical based concepts such as mole and atomic theory. The findings favored the experimental method. Karplus (1977) found Karplus cycle superior to a lecture-type method. Moreira (1978) compared the usefulness of two teacher-centered expository methods; envisioned and proposed by Ausubel, the other a traditional expository natured one. The findings favored the Ausubel’s approach. On the base of the above findings the traditional instructional method came under criticism and the innovative constructivist method succeeded to get support and encouragement because this method ensures the
active participation of the students in the learning situation and builds new knowledge on the base of the information gained from the environment.

Robinson and Niaz (1991) compared the interactive approach with the traditional lecture method on the solution of stoichiometry problems and the interactive group was found more successful.

Odubummi and Balogan (1991) compared the performance of laboratory-based method and lecture method for the teaching of biotic and abiotic concepts. The laboratory –based teaching enhanced the learning and particularly the low performers performed better. Laboratory-based method was found helpful in the concept formation by Westbrook and Rogers (1996) by using Karplus’ learning cycle for the concept of flotation.

Hand and Treagust (1991) undertook a longitudinal study to investigate the effectiveness of constructivist versus traditional method with tenth class students studying the concepts like acids and bases. The students of constructivist method outperformed the non-constructivist students.

Cohen (1992) undertook a study to compare the effectiveness of activity method and verbal method for the teaching of Geological concepts. The comparison made it clear that the activity method, being constructivist in nature, was found more beneficial than the verbal method. Simultaneously it was revealed that the activity method proved more helpful for average and low achievers.

Cavallo and Shafer (1994) while teaching biological concepts found that when student’s determined to learn in a meaningful manner, their intention contributed to their learning with understanding. The meaningful learning course was found interactive with the prior knowledge and proved as a predictor of meaningful understanding.
Research has pointed out the unpopularity and irrelevance of chemistry teaching in the eyes of learners (Kracjik et al. 2001; Osborne and Collins, 2001; Pak, 1997; Sjoberg, 2001; WCS, 1999; ICASE, 2003). Chemistry teaching is not promoting learning with understanding (Anderson et al. 1992; Zoller, 1993). There exists a gap between chemistry teaching and the demands made by the learners (Hofstein et al. 2000; Yager and Weld, 2000; Holbrook and Rannikmae, 2002). Teaching of chemistry needs to be changed and teachers also need guidance in this regard (Aikenhead, 1997; Bell, 1998; Rannikmae, 2001a). The above discussion indicates the deficiency of relevance especially with respect to the development of conceptual understanding and the sense of appreciation in the learners for chemistry and the scientists (Pak, 1997; Yager, 1997; Champagne et al. 1985; Lederman, 1992; Novick and Nussbaum, 1981; Osborne and Freberg, 1996; Rayan and Aikenhead, 1992). Hollbrook (2005) pointed out that relevance of teaching of chemistry to our environment, future employment and future developments in society carries more importance. He suggests that the teaching of chemistry needs to be linked to our daily needs. It implies that chemistry teaching should help the learners to understand and appreciate the prevailing contemporary socio-scientific issues within the society. Hollbrook (2005) demanded a shift of emphasis in the teaching of chemistry. He suggested that there must be a shift from learning with understanding within the subject context to learning with understanding in a social context. Teaching of chemistry must be geared to the goals of education.

National Education Policy (1998) stated that the quality of education is directly related to the quality of classroom environments. Quality of education can not be improved without improving the quality of teaching. The teacher’s pedagogical content knowledge is basic to the quality of teaching. It was further pointed out that
the obsolete theories and practices are continuously deteriorating the quality of education. It means the present theories and practices of teaching and learning need to be revisited.

National Educational Policy (2009) has also expressed quite dissatisfaction over certain initiatives taken and traditional approaches for improving quality education, delivery, teaching quality and learning environment. The initiatives lacked coordination and are not benefiting the national objectives. The policy also showed discontent over the quality of teachers in public sector and stressed need of research based teacher training. The policy envisaged to relate the teacher training in science according to the real life situations (i.e. contextual) and urged the use of all resources that will help to promote science at all levels.

1.2 Statement of the Problem

Science has been recognized as critical need of every society. The dream to promote science can not be realized until the science teaching is made scientific, systematic and organized. Like science the teaching methods need to be made scientific to improve the prevailing picture. The study aimed at comparing the effects of Johnstone’s three cycle instructional model and the traditional instructional model.

1.3 Significance of the Study

Taba (1962) pointed out that the education must emphasize on individual development as its chief function. The educational efforts should develop all the powers of the individual, in other words the “whole-child”. Therefore the talent of each child is to be sought out and developed to the fullest. Each weakness is to be studied and as far as possible be corrected.
The school as a change agent and socializing agent can do the above mentioned jobs which are its core responsibility.

- The study may contribute to better concept formation and conceptual understanding particularly in chemistry as well as be helpful to develop higher order cognitive skills in students.
- The study may also contribute to meaningful learning and conceptual understanding.
- The study is likely to give school chemistry education a new direction and momentum.
- The study may help to devise the ways to relate different forms of concepts of chemistry envisioned in the ways of learning.
- The study may help to rejuvenate and revive the chemical values to all students as well as restore the interest of the students in chemistry.
- The findings of the study may help the teachers to understand the mechanism of learning and problem of unfamiliarity posed by technical language of science.
- The findings of the study are likely to help curriculum planners and developers to redesign and reshape the chemistry curriculum.
- The findings may help to revisit the contents of teacher training courses.
- The study may provide a base for conducting further researches in the pedagogical content science.
- The study may also provide guidelines for content sequencing in physical sciences.
- The outcomes of the study may help to remove the latent learning obstacles resulting from subject specific language.
• The users of the study are likely to be science teachers, curriculum designers and developers, Secondary Educational Boards, National Book Foundation, Pakistan Science Foundation and Text-book Boards.

• The findings of the study may go a long way to help the teachers to design their lesson plans according to student’s information processing capacity. Because each and every individual has fixed and limited working memory space and above that the learning process gets blocked (Baddeley, 1999).

1.4 Objectives of the Study

The current research study was envisioned to investigate:

➢ Relative effectiveness of Johnstone’s three cycle instructional model and traditional instructional model on student’s learning and achievement in chemistry at secondary school level.

➢ To uncover the effects of content sequencing as conceptualized by Johnstone in the chemistry laboratory.

➢ To provide set of recommendations for the improvement of concept formation in the learning of chemistry.

1.5 Delimitations of the Study

The following were the delimitations for this study:

• Instructional methods have a number of variants with respect to effectiveness and applicability. No teaching method is inferior or superior but their use is highly dependent on the situation. The current study is delimited to an evaluation of Johnstone’s three cycle instructional method and traditional lecture method.
Keeping in view different constraints such as non-availability of schools, treatment feasibility, controlling the school environment, school schedule and lack of time, the sample was selected from a single school. The use of single school makes the intervention and treatment more manageable and easier.

The sample selected for the study comprises of two groups of 9th grade secondary school science students of Federal Government Boys Model School F-8/3 Islamabad. Each group was made up of of 38 students. Accordingly the study was constrained to seventy-six 9th graders studying chemistry.

The study was restricted to the subject of chemistry for 9th grade students.

The dependent variable was limited to achievement only.

The study was also restricted to only male students.

### 1.6 Hypotheses of the Study

**H_{01}.** There is no significant difference between the achievement scores of students in the subject of chemistry (theory) taught through Johnstone’s three cycle instructional and traditional instructional method as measured by formative assessment tool.

**H_{02}.** There is no significant difference between the achievement scores of the students in the subject of chemistry (practical) taught through Johnstone’s three cycle instructional method and traditional instructional method by formative assessment tool.

**H_{03}.** There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method as measured by formative assessment tool.
Ho4. There is no significant difference between the achievement scores of students in the subject of chemistry (Theory) taught through Johnstone’s three cycle instructional method and traditional instructional method as measured by the formative assessment tool.

Ho5. There is no significant difference between the achievement scores of the students in the subject of chemistry (practical) taught through Johnstone’s three cycle instructional method and traditional instructional approach as measured by the formative assessment tool.

Ho6. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory +Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method by the formative assessment tool.

Ho7. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s three cycle instructional method and traditional instructional method by macro assessment tool (MALAT).

Ho8. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method by the macro assessment tool (MALAT).

Ho9. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method (MALAT).
Ho10. There is no significant difference between the achievement scores of the Students in the subject of chemistry (Theory) taught by Johnstone’s three cycle instructional method and traditional instructional approach (MILAT).

Ho11. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method (MILAT).

Ho12. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s three levels instructional method and the traditional instructional method (MILAT).

Ho13. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s three cycle instructional method and the traditional instructional approach (SLAT).

Ho14. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s three cycle instructional method and the traditional instructional method (SLAT).

Ho15. There is significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s three cycle instructional method and the traditional instructional method (SLAT).

Ho16. There is significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s three cycle instructional method and the traditional instructional method on post-test.
Ho17. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method on post-test.

Ho18. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s three cycle instructional method and traditional instructional method on post-test.

1.7  Procedure of the Study

Any experimental study for its valid conclusions heavily draws on data that is collected by valid and reliable instrument. This condition can only be met by standardized instrument. Since the area selected has not been investigated. Consequently the researcher himself formulated achievement test to discover the level of improvement of the students. The study used the following instruments to achieve the objectives.

- Previous scores in the 8th class science were used to equalize the two groups (experimental and control).
- Post-test (Theory) in the subject of chemistry for measuring achievement
- Post-test (Practical) in the subject of chemistry for measuring achievement
- Macro level assessment tool
- Micro level assessment tool
- Symbolic level assessment tool

The study intended to compare the effects of Johnstone’s instructional method and traditional instructional method on student’s achievement. The experiment was
conducted for 22 weeks in the chemistry classroom and chemistry laboratory of Federal Government Boys Model School F-8/3 Islamabad.

1.7.1 Research Instruments (Construction, Improvement and Validation)

1. Achievement Test in the Subject of Chemistry for 9th Grade Secondary Science Students.

   According to the content of the study and Blooms Taxonomy achievement test (i.e. Chemistry Part I) of 75 marks (theory 65 marks and practical 10 marks). The test underwent the stages are:
   1. Planning stage
   2. Development stage
   3. Try-out stage
   4. Evaluation stage

2. Macro level Achievement Test

   The test was designed to measure the macro level gains in the subject of chemistry. This achievement test carried 23 marks (theory 20 marks and practical marks).

3. Sub-micro Level Achievement Test

   The test was designed to measure the micro level gains in the subject of chemistry. This achievement test carried 20 marks.
4. **Symbolic Level Achievement Test**

The test was designed to measure the symbolic gains in the subject of chemistry. This achievement test carried 20 marks.

1.7.2 **Population of the Study**

- There were fifteen boys, secondary schools in the urban area of Islamabad in the year 2010. Out of fifteen schools only one school was selected.
- All the secondary science students comprised the population of the study.

1.7.3 **Sample**

Federal Government Boys’ Model F-8/3, Islamabad was randomly selected as a population for this study. There were 130 science students in Federal Government Boys Model School F-8/3 Islamabad during the school year 2010-2011. Seventy-six science students were randomly selected as a sample for this study. The 8th class science achievement data of school year 2009-2010 was obtained from school administration by the researcher. On the basis of this data the sample was then divided in to two equivalent groups. The descending ordering approach was utilized. The sample was then given the shape of matched groups’ i.e.38 students in the experimental and 38 students in the control group on even/odd principle. There was no loss of any student and equal number of students of each group completed the experimental period.

1.7.4 **Administration of the Research Tools**

The research devices for this study were executed to the sample at a stated time as mentioned in the time schedule.
1.7.5 Data Processing

By utilizing the measurement procedures the data was collected, processed and given the shape of mean scores. On the basis of the comparison of the mean scores and statistical analysis, the results of the research were presented in the chapter four. Keeping in view the results the findings were made and conclusions were drawn.

1.7.6 Domain of the study

The domain of the study consisted of:

- Chemistry textbook for secondary classes (part I) published by Punjab Text-Book Board Lahore.
- Ten practicals mentioned and recommended in National Curriculum Chemistry 2000 and Federal Board of Intermediate and Secondary Education Islamabad.

1.7.7 Time Table of the Research Study

The experiment was carried out for the period of 22 weeks in the chemistry Classroom and laboratory of Federal Government Boys Model School F-8/3 Islamabad. The experimental group was treated by Johnstone’s ‘three-cycle’ instructional method while the control group was taught with the use of the traditional method by another science teacher of the same institution.

The researcher also utilized the zero period facility as a relearning in the form of lecture one day before the commencement of the practical work. The laboratory work was optimally utilized so that the students may construct knowledge. When the students construct knowledge they learn more efficiently and effectively. The students were encouraged to bring new ideas to the classroom and laboratory. More time was
devoted for macro level learning because its usefulness was recognized by Johnstone (2000) and he suggested taking start from concrete experiences. The research study period was divided into three parts such as macro period, sub-micro period and symbolic period. The activities consumed more time because learning was directed from concrete to abstract. At the end of each stage three formative assessments were conducted by the researcher for feedback purpose.

The research timetable was exclusively harmonized and synchronized with the institutional time table.

1.7.8 Research Design

“The post-test only equivalent group design” was used for this research study. This design involved two groups’ i.e. experimental group and control group. Both the groups were randomized and equalized on the base of achievement of 8th grade science test.

*Figure 1.5* The symbolic representation of the research design

**Post-Test Only Equivalent Group Design**

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1.7.9 Analysis of Data

- The independent sample $t$-test was used to find out the significant difference between the two means at a selected probability level (i.e. $\alpha = 0.05$).

- Kuder Richardson (KR 21) formula was applied to find out the reliability and consistency of the measurement procedures.

- To test the hypotheses set for this study, the $t$-test was applied to analyze the data. The hypotheses were accepted or rejected on the base of comparison of $t$-calculated and $t$-tabulated values.

- The data was analyzed with the use of the software (SPSS) version 19.
CHAPTER 2

REVIEW OF THE RELATED LITERATURE

This is the scientific and technological era and the prominent features of this era are the progress, technology, development, and the ceaseless series of changes that have left significant impact on the human life. Improvement in each and every field of life has been the prime objective of human beings. Improvements wherever visible are the outcome of science. Science of learning and the science teaching are equally important.

This chapter is a significant endeavor to critically summarize the human efforts in different ages to improve the teaching of chemistry. The researcher has critically analyzed the different research efforts made in the field of teaching and learning by learning scientists, teaching scientists, educationists and psychologists.

The 20th century witnessed and experienced knowledge explosion in every field. There was hefty increase in the knowledge base of every subject and discipline. The science of teaching and learning went under radical transformations to cope with these changes and to solve the complexities of various subjects and disciplines. Science education stepped forward and undertook the responsibility of solving the problems and removing the hurdles that are frequently faced by the science of instruction and learning.

NRC (2000) pointed out that the study of mind witnessed significant and crucial changes in the last three to four decades. These changes proved fruitful and worthwhile for education and learning. This endeavor shifted the understanding of the concept of mind from speculation to science. NRC (2000) stated that research efforts are in full swing to solve the problems of learning and transfer and have successfully discovered certain principles that are fundamental and have succeeded to uncover
important principles for organizing learning experiences that ensure the transferability of the concepts, laws and principles and enable the learners to apply these in novel situations that are entirely different from the previous ones.

2.1 Science and its Scope

It is a common misconception that science is just a pile of ideas, thoughts, and concepts that are true or an organized body of knowledge. This misunderstanding needs to be corrected. Science is taken both a well organized and structured form of knowledge and a method of constructing that knowledge. Science has a number of facets:

- Science is not fragmented and disorganized collection of facts but it is both a well organized form of knowledge and also procedural in nature.
- Science is a method of discovering and investigating.
- Science is useful, powerful and reliable.
- Science is always dynamic, ongoing, continuous and never static.
- Science is individual to some extent but overall a global human endeavor.
- Science is tentative.

Scientists are continuously struggling to understand the natural phenomena. It is no doubt that science is complex, difficult and multi-faceted but has important tenets which are straightforward.

- The exclusive focus of science is natural world, not the supernatural world.
- Science unearths the secrets of this natural world and helps us to learn these secrets.
- Science is testing of ideas and figuring out expectations from these ideas.
Science is a community endeavor. It has a proper check and balance therefore, it has greater precision and accuracy.

Science affects our everyday life.

Science is accessible to everyone.

As science is directly related to our lives therefore while teaching the teachers must elaborate and clarify the scientific concepts by furnishing daily life examples. All the technologies, medical advances, and the knowledge that improves day to day life are partly the result of scientific method. Science is deeply interwoven with our daily lives. Science affects us in every moment of our life. Without modern science there would be no modern facilities such as power which has revolutionized this planet. Now this is the age of polymer and no one dies of hunger due to modern agricultural revolution.

Baddeley (1994) went farther in assigning roles to science He revealed that science is an attempt and an effort to understand the mysteries of this real world. As human is an important part of nature therefore science also tries to comprehend and understand the way human learn, and also intends to express these understandings in some intelligible and comprehensible way i.e. a theory, a law or a model.

Science can be represented in an undeviating style and it can be represented as

- Inquire a question
- Formulate tentative answers to the problem or hypothesis
- Design and devise experiment to find out the answer
- Collect evidences in favor of a problem or against that problem
- Find out the validity and reliability of the gathered evidences or draw valid conclusions from the evidences.
2.2 **Significance of Science Education**

Science is an ideal subject not only to solve real world problems but also to improve and refine the thinking ability of the students. The way forward to seek critical thinking is the improvement in science education. Science education is not static but dynamic in nature and it is in a continuous state of rearrangement and reorientation. “Teaching and learning” has been an important vehicle for transmitting past achievements to the young generation. The task of science education is more important than this. Science education has to shoulder dual responsibilities i.e. not only to transmit the past experiences but also to utilize these past experiences in the promotion of knowledge. Science education has always been trying to take the turn and revisit the prevailing transmission principle and design the ways that help to understand how to make this transmission more effective in the perspective of learner styles. One method is not a panacea of all problems. The mere transmission genre of teaching has ever been disputed and doubtful. Science education remained steadfast to portray and repaint the prevalent and prevailing picture. The major task of science education ahead is to make future citizens scientifically literate in particular and society in general. The crucial job of science education is to furnish with such an environment that is conducive to make sense of what is happening around them. Most apparently, science education has to create and promote the interest among the students not only for science education but also for the way to learn science. Science education has also to promote and forward the competencies of the students for the application of scientific and technological concepts for the personal and societal benefits. The applications of scientific concepts necessarily transcend the global boundaries.
Bybee (1997) conceptualized that any society can achieve its goals. Science education is continuously playing a crucial and significant role to make the society develop in all spheres of life. In nutshell it can be envisaged that the final and end target of science education is to promote and forward the concepts and principles of science that are intended to raise and enhance the quality of life.

DeBoer (2000) thinks that it is quite unjust to confine science education to only scientific literacy. It seems that the science education and scientific literacy have common goals.

Science education must always be ready to achieve a critical objective i.e. devise ways to improve the scientific literacy and ensure to prepare the future people for the coming challenges that will be product of science and technology. Therefore science education has to make arrangements for the coming challenges. (Bybee and Fuchs, 2006).

Science education should strive to achieve the following goals:

1. To develop the skills that prone to build scientific knowledge i.e. the way science works.
2. To make available new scientific and technological concepts and principles.
3. To use the scientific competencies that is the result of learned scientific concepts and principles not only for self but also for others.
4. Attitude is basic for learning therefore science education designs strategies to develop and enhance attitude.
5. The scientific concepts and principles must be related with the environment and society. In other words these might be rooted in the society and environment. Science and technology can not operate in isolation and surely interacts with the society and a number of issues are likely to be produced by
the applications of scientific concepts and principles that directly or indirectly affect the individuals in particular but society as general. (NSTA, 1982).

NSTA (1982) stated that while framing, planning and designing the science courses the following features of the scientifically literate person need to be kept in view.

1. Becomes able to use the learned scientific concepts, certain procedural skills and on the base of these develops the ability to make decisions that show responsibility.

2. Develops the sense of mutual and reciprocal influences of society, science and technology and the way these influence.

3. Understands the role of society in controlling science and society by materializing these.

4. Develops the ability to identify the boundaries and benefits of science and technology and their role in uplifting and elevating the standard of human life.

5. Should be well versed with the basics of scientific knowledge as well as core ideas that scaffold the later learning.

6. Develop the ability to appreciate the role played by science and technology.

7. Understands the ways and means that are conducive to the formulation of scientific facts and concepts.

8. Develops the ability to make a difference between scientific proofs and the opinions that are personal in nature.

9. Identifies the developmental stages of science and the scientific concepts are likely to be revised with the passage of time i.e. possess tentative nature and how the scientific knowledge undergoes modifications.
10. Develops the abilities to understand the effects and influences of the scientific principles when applied.

11. Becomes fully aware and cognizant about the role of science and technology and the sense to appreciate.

12. Has an amusing and more stimulating outlook of the world as the result of science education.

13. Develops the ability to appraise and assess the value of scientific concepts and principles in the sense of consistency and steadfastness in providing basis for decision making.

It can be said that the above stated attributes of a scientifically literate person are the targets that the science education intends to achieve. The characteristics of a scientifically literate person are in real sense the intended learning outcomes. Different aspects of scientifically literate person afore mentioned are broad in nature and need to be made specific and translated in to instructional objectives to make these attainable. The translation of the above mentioned facets and peculiarities of a scientifically literate person is very important while teaching and learning situations are going to be designed and conceptualized.

It can be said that science education intends to produce citizens that have mastered the basic science concepts, processes and skills that are necessary in decision making and encounter the life situations and are prepared to lead a successful life in a complicated society as a scientifically literate person.

2.3 **Scientific Literacy**

NRC (1996) identified the basic functions that are performed by the scientific literacy i.e. help the learners to apply the learned scientific concepts. It also enables
the learners to apply these concepts while making important decisions in their daily life. Another important challenge that scientific literacy finds ahead is to enable the learners to actively participate in the public discourses and make their personal decisions. It has to create awareness regarding the scientific issues and express their opinion about these.

Shen (1975) identified three categories of scientific literacy on the basis of its functions such as, practical, civic and cultural. Similarly Shamos (1995) hierarchically classified scientific literacy and gave it three forms. He further explained that the levels identified serve as a prerequisite and foundation for the successive levels.

The above stated references are in essence the criteria and a yardstick of scientific literacy. Roberts (2007) theorized two forms of scientific literacy and named these forms as levels.

1. First level is purely concerned with scientific facts, processes, skills, and further development of scientific concepts that assist the learners in their concept formation stages. The first level deals with what the students should learn and is textual in nature i.e. concepts processes and skills necessary for literate life. The first form concurs with the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1990, 1993).

2. The second form is applied in nature and helps in decision making when the individual encounter the life situations and in certain situations he has to make judgments and make wise decisions to solve socio-scientific issues (Sadler and Zeidler, 2009), contextual issues (Nentwig et al. 2006) and science technology and society issues.

Nentwig et al. (2006) rightly claim that this modern period is absolutely the product of science and technology and is extremely intricate and the individual must
get the ability to anticipate, foresee and be able to give meaning to the information gained through a variety of resources. The knowledge that is obtained by the traditional ways in science lacks meaningfulness and so the students fail to find the solution of the problems that are scientific encompassing their life span. Life long learning is the desired end of scientific literacy so that the individual can encounter the real life problems embedded in real life situations.

When the ways of knowledge acquisition are not going towards knowledge ability then microanalysis of the school programs is needed. All the traditional ways and means need to be revisited.

Berns and Erickson (2001) identified certain critical and important factors that if incorporated can change the scene i.e. the strategies like problem solving, independent learning, and learning from age mates.

Program for International Student Assessment (PISA) is a very significant development in the field of scientific literacy. It has policy orientation and provides policy oriented indicators of skills and knowledge for secondary stage learners and anticipates the factors that are contributory in nature in the growth of students, schools and the science education system (Bussie & Pennock, 2007).

Scientific literacy is four featured.

- It involves the scientific knowledge of the individual and helps to recognize the problems having importance, formulation of new and the networking all these concepts, interpretation and explanation of the phenomenon.

- Scientific literacy fortifies human abilities to grasp the significant features of scientific knowledge.

- It creates awareness about the functions performed by science.
• It creates readiness to encounter the issues that are the direct or indirect outcome of science. Scientific literacy intends to see and prepare the citizens that participate actively in the routine matters. (Organization for Economic Cooperation and development [OECD], 2006).

PISA (2006) is comprised of four components or aspects i.e. scientific contexts, scientific competencies, scientific knowledge and attitude toward science. PISA laid emphasis on the scientific capabilities and proficiencies, discernment and making of scientific concepts intelligible and it ensures the applicability of these competencies in diverse life situations.

The domain of scientific literacy encompasses both knowledge of scientific concepts and the procedures and methods of science. The scientific knowledge includes conceptual understanding of these basic science concepts. The other important facet of scientific literacy is the development and improvement of the methods of science that are a basic source to create the scientific knowledge. The focus of scientific literacy is to help the learners in learning the basic science concepts and how to develop the learning with understanding of the scientific knowledge and concepts. The other major intention of the scientific literacy is to prepare and train the learners to face real life situations and to be able to make decisions.

PISA is a conceptual structure with multiple components, interpretations and mainly aiming at student conceptual understanding and assessment in science. The conceptual framework and structure is given as under:
Science education can be viewed as a system and is further composed of subsystems. Basically science education has to support real life activities in an organized and systematic way. This important objective seems to be realized when science education continuously prepares the highly scientifically literate persons in order to support the societal functions NRC (1996). The practice of science system can be influenced by the three systems. Fig. 2.3 presents a very vivid interrelationship between these three systems and how these systems influence each other in the form of diagrammatic representation.

From OECD (2006).

From NRC (1996).
The figure illustrates the overlap of the three systems that influences the practice of science education. All the three systems are highly interdependent. Functional harmony in science education is achieved through coordination. All the systems are interactive in nature (NRC, 1996).

2.4 Meaning, Scope, and Importance of Chemistry

Chang (1996) states that chemistry is basically related to the study of material objects and the changes these undergo. In broader sense, chemistry is a physical science. Chemistry not only deals with matter but also all distinguishes matter in to subcategories based on composition and properties. Reid and Mbajiorgu (2006) pointed that chemistry is an important tool that helps us to develop our basic understandings and continuously adds to all spheres of life. It underpins our understanding at atomic and molecular levels. Tsaparlis (2000) added that chemistry is a molecular science: a sub micro-world of molecules, atoms, and electrons. He further stated that chemistry deals with the small as well as the large world simultaneously.

According to Tsaparlis (2000) chemistry education has ever undergone radical changes and took turn from theory and logic-oriented nature to application. As a result new programs were introduced which had practical orientation towards technology-and-society? Various serious attempts were made to make chemistry relevant to everyday life and society i.e. Science, Technology, Environment and society (STES) Salter’s, Chemistry in context, and ChemCom. Chemistry should be correlated to the issue and problems that are important to the whole society in which science of chemistry has direct or indirect involvement e.g. environment, energy, natural resources, issues of human health, agricultural matters. Attempts have also been made
to make science of chemistry enjoyable. Reid and Mbajiorgu (2006) suggested that Chemistry should address the prime themes of life which are important for the society as a whole e.g. daily life items and activities such as dyeing, cooking, cleaning, cleanliness, drugs, medicines analysis and resources. They further suggested that the starting point should be personal and societal issues. The above discussion envisions the way through which we should provide the learning experiences to get the required outcomes.

Chemistry is called the central science because it has responsive nature and tries to fulfill our basic requirements and aspirations of our society. It has been serving the mankind before the birth of humanity. Chemistry is contributing to every field of life. The role of chemistry as a central science is not a matter of dispute because the statistical figures provide evidence in favor of this assertion. The responsive and need satisfying nature of chemistry is strikingly verified by the statistics on the number of professional chemists employed by the industry. Chemistry fits in to our lives. It informs us about the new frontiers that are being opened by it and the benefits that may flow from it. It also shows that how chemicals are important to our survival. A number of changes continuously take place around us which are always significant. We see articles made of iron corrode, living things grow. Burning changes the nature of the things. We can say that one type of chemicals change to another type. Due to these changes one form of matter changes to another form. Chemistry deals with such changes. In real sense these changes are chemical reactions. These chemical changes serve to change nonliving matter in to living matter and if these changes are ceased there will be no life on this planet. All life processes i.e. photosynthesis and respiration are chemical processes in which one type of chemicals are converted in to another type of chemicals. Photosynthesis helps to
solve the problems of humanity by converting water and carbon dioxide into food which is and has been the problem of humanity. In short it can be said that our problems and their solution is hidden in the chemical changes that are ever taking place around us.

2.4.1 Chemistry as a Collaborative Effort

Collaboration and cooperation is the central element of nature of chemistry (McComas and Olson 1998; Osborne et al. 2003). It is a common attribute of science and chemistry. Vesterinen & Askela (2009) critically analyzed the nature of chemistry related issues and perceived that chemistry has collaborative nature. They further claimed that science is a collaborative effort and this effort is not restricted to any particular region but it is worldwide in nature. All scientific communities are collaborating for the worldwide common good.

2.4.2 Chemistry and Interdisciplinary

Vesterinen and Aksela (2009) revealed that scientific activity along with its growth is becoming complex and needs to transcend the limits of specializations. They further realized that interrelationship among the scientific disciplines is the need of the hour and ought to be enhanced. They take interdisciplinary as sharing, trusting and integration of scientific ideas among the varied scientific disciplines. Sanz et al. (2004) noted opposing developments in the growth of the scientific discipline i.e. emergence of scientific specialties and on the other hand different areas are going to be combined for the benefit of humanity. NRC (1987) reported that the traditional concept of specialization is diminishing and there is move towards interdisciplinary and cross-disciplinarily.
2.4.3 Chemistry and Society

NRC (1985) claimed that the prime objective of society has been to improve the standard of living. Chemistry having responsive and contributory nature helps to conceive the crucial and important needs of society. It also attends those needs that are indicators of the standard, quality and economic strength of life. Quality of life is directly or indirectly related to the advancement, development, application, and overall of chemical knowledge. Vesterinen and Aksela (2009) view science as responsible for technology advances for industry and society. They further concede that technology advances are applications of scientific knowledge. They called applications as linear model of science. The linear model of science which brings about chemical technology advances is illustrated by the following figure.

Figure 2.5 Linear representation of science

Basic research → Applied research → Development → Production and operation

From Vesterinen, and Aksela (2009)

Sjostrom (2007) conceptualized a close relationship between science, technology and chemistry. He viewed that formation of new compounds and understanding their structures is a joint venture of chemistry science and technology. Dakers, et al. (2007) revealed that the emerging scientific knowledge and technological advances will bring about socio-cultural changes.

Jonstone (2000) stated that chemistry is full of aesthetic, intellectual value and is quite enjoyable. Tsaparlis (2000) designed an approach called SOMA to make the chemistry teaching learning process affective, beautiful, aesthetic and enjoyable subject and it maintained the views of Johnstone (2000)
Chemistry is practically oriented towards technology-and-society and the approaches making chemistry every day science are Salter’s, Chemistry in Context and ChemCom addressed and established the connections between the chemistry and every day life (Tsaparlis, 2000).

Now chemistry teaching and learning process has varied resources and is attempting to cater for the needs of diverse learners. Chemistry teaching and learning process provides hands-on activities according to their interests and involve learners in the learning process. Nespor (1987) identified science teachers, their knowledge, attitudes and beliefs as neglected aspects of the teaching learning process. Later Shulman (1986, 1987) presented a set of elements called pedagogical content knowledge that underpins the teaching learning process and visualized its necessity to deal with the learner diversity, knowledge diversity and to bring about precision and accuracy in the teaching and learning process. Jonstone (2000) noted the traditional approaches as being unsatisfactory and demanded the restructuring of the school science particularly the pedagogical practices. He recommended that the school science edifice be constructed on logical and psychological ground.

Mbajiorgu and Reid (2006) asserted that the aim of any school chemistry should be broader than in vogue i.e. chemistry should contribute to all sorts of knowledge and should transcend the traditional boundaries. The school chemistry should generate informed citizens that are well cognizant about chemistry and its importance in modern day society. The citizens should have positive affections towards chemistry. They further suggested that the school chemistry should be taught to meet the needs of higher education and the vertical conceptual movement. It means that the school chemistry should always be ready to cater for the needs of higher
learning. The teaching of chemistry should have heterogeneous setting and provide access for all students.

Tsaparlis (2000) noted the two broader functions that the school chemistry should perform, are:

- Profound learning of chemical facts, concepts and principles that are essential for living.
- Chemical culture i.e. the deeper and thoughtful understanding of how nature functions chemically.

Chemistry panel of NRC (2002) agreed that the high school chemistry should provide students with:

a. Atomic-scale view of matter
b. Connection of micro and macroscopic physical and chemical properties.
c. Language used to express the micro and macro relationships.
d. Using periodic table as organizing entity.
e. Experimentation and scientific methodology.
f. Enable the students to develop the ability to grasp and explore the chemistry concepts and laboratory practices.
g. Application of learned knowledge in every day life.
h. Development of critical thinking skills and deeper conceptual understanding
i. Development of inquiry attitude
j. Development, promotion and growth of communication skills and teamwork.

NRC (2002) summarized that school chemistry should attempt to (i) enhance scientific literacy and (ii) preparation for further study and preparation for every day life.
Mbajiorgu and Reid (2006) stated that school chemistry should help the students to
develop the skills that might contribute to benefit both society as well as chemistry.

2.5 Teaching of Science

Up to 1900 the notion was that science was just a form of knowledge and other important features of science remained out of sight. This perception remained in practice and carried the conviction that science should be learned by direct instruction. But later this concept went under revision when criticized by Dewey (1910). Dewey changed the direction and helped to reshape and reformulate the nature of science. Dewey called science a method or a process. The systemic and universal reform efforts continued and culminated at the formulation of science education standards (1996). The standards envisage that science must not be confined to procedures and simple processes which serve to build the concepts of science. Educators and investigators strongly agree that an environment that encourages inquiry provides best opportunities for all kinds of learners to learn. Inquiry is central to learning because students learn science by doing and engage themselves in the varied learning experiences. The students develop critical and logical thinking while constructing explanations. The programs like PSSC, BSCS, and CHEM. STUDY committed to provide opportunities and engage students with phenomena. Schwab (1962) has a very fine and concentric view of learning and portrayed learning as “enquiry into enquiry”. In this the teacher’s responsibility is to set up hands-on and investigative science experiences like a scientist in a laboratory. Curriculum developers and educators believe that engagement or learning by doing is very helpful and suitable in attracting students towards science.
Science Curriculum Improvement Study (SCIS) although influenced more by theories of teaching and less by theories of learning proposed a “learning cycle”. The learning cycle included the following steps:

1) Exploration of a concept. This objective is achieved through practical work. During this phase the students have concrete experiences upon which they continue to construct their knowledge and skills. Actually this is engagement and learning by doing phase of the cycle.

2) Conceptual invention. This phase is built upon the first phase i.e. concept invention. This may be called derivation stage in which the students use the gathered experimental data after rigorous peer and teacher discussion.

3) Concept use. This step deals with the application of newly acquired and learned scientific laws, principles and concepts.

Specific bodies of knowledge are prerequisite to learn and apply 21st century skills (NRC, 2008). In science education; students can develop cognitive skills when engaged in specific topics and concepts. To develop the 21st century skills in the students that make them eligible to face the challenges ahead that are result of scientific and technological progress. Bybee (2010) proposed an inquiry oriented instructional model. The model is commonly known as BSCS or 5Es. BSCS and if it is based on current research in teaching and learning. It has world research recognition by cognitive scientists (Brooks & Brooks, 1993; Driver et al. 1994; Lamber et al. 1995; Mathews, 1992; NRC, 2000; Piaget, 1976; Posner et al. 1982; Vygotsky, 1962). Cognitive research while discussing the nature of learning indicated that learning can not occur without active participation of learner so it is active in nature and activeness is central to learning and understanding. Thus learning is the result of combined act of
the information encountered and the way of processing information by learner and knowledge held by the learner. BSCS consists of the following phases:

1. Engagement. This step makes use of the learner’s earlier ideas and on these preceding ideas, active learning experiences are designed. These activities act as connectors and organizers of the concepts to be learned. Previous knowledge is used for diagnosis and for connecting it with the past.

2. Exploration. This is an identification stage and is used to bring about conceptual changes. The learners are active and the principle of “learning by doing” is used to rectify the misconceptions. New ideas are generated and useful knowledge is constructed. This step is investigative in nature.

3. Explanation. In this stage the students are provided opportunities to demonstrate their conceptual understandings of the learned concepts. The teacher is to facilitate the learner in learning situations and explanations are provided by the teacher.

4. The teacher challenges and extends the conceptual understanding to the students with the result that there is engagement and direct manipulation with objects and the demonstrated skills. After deeper understanding the students apply the concepts and ideas.

5. Evaluation. The teacher assesses the students’ level of understanding and provides them feedback for further improvement and motivation. He informs the learners where they stand.

Engle and Conant (2002) outlined the essentials of domain specific engagement/disciplinary engagement.

Scientific inquiry while engaged in teaching learning process should focus the following integrated domains:
Scientific inquiry should focus the scientific reasoning and way of thinking. It can be further added that scientific inquiry should find the ways that are conducive to develop conceptual links.

The useful scaffolding to construct scientific concepts.

The knowledge construction should also be based on collaboration, cooperation, peer learning and team work.

Devise learning situations that involve student centeredness.

Instructional sequences that are supportive in nature and are helpful to promote science learning.

Arrange practical experiences that enhance the tangibility of the concepts.

Conduct frequent assessments that are helpful to monitor and provide effective feedback about the learning status of the learner.

Miller (2010) unveiled science as a product, a process and an activity. The scientific knowledge explains the material world. This scientific knowledge has its own ways and criteria to address the question, and to accept the answers. It also gives ways of knowing; testing procedures, sorting out knowledge claims and establish scientific community for critical review and evaluation. The scientific knowledge is always tentative i.e. open to revision but the core and main elements of scientific knowledge are quite established. The intrinsic value and success of scientific knowledge is due to appropriate ways of knowing and testing. Science purposefully helps in acting on the materials, objects and events. In order to meet the objectives and requirements of constructing knowledge, Millar (2010) identified the following major aims of science education

1. To help and facilitate the learners to gain the conceptual understanding of scientific knowledge according to their needs, interests and capacities.
2. To help and facilitate the learners to develop and understand the ways of knowing and the methods to gain the scientific knowledge.

The students must be well versed and cognizant about the implicit and explicit methods and means that are aimed at forwarding the scientific concepts and principles. There are more reasons why science educators put more emphasis on scientific knowledge.

   a. Better conceptual framework of scientific knowledge and scientist’s reasoning and argumentation is helpful for learning the scientific content.

   b. Explicit understanding of the scientific concepts and principles is at the core of modern citizenry. The people have to learn the latest concepts in order to lead a successful life.

   c. Science must not be restricted to only one form of knowledge but it is a procedure to find out the solutions of questions and problems. The previous notion regarding science has undergone revision, more than a body of knowledge.

Irvin (1995) identified two aspects of scientific knowledge i.e. “enlightenment” and “critical”

While commenting on the conceptual understanding and learning scientific knowledge. Committee on Prospering in the Global Economy of the 21st Century (2007) warned against the following bad consequences of poor conceptual understanding. These are (1) production of individuals having poor scientific ideas (2) serious economical and occupational implications.

Several international comparative studies such as TIMMS, PIRLS, PISA show that the performance gaps among the international students are entirely due to the differential conceptual understanding. Ketelhut (2010) investigated the
relationship between interest in career and conceptual understanding and found the relationship positive. Similarly Johnstone (2000) recorded some unpleasant and depressing facts which showed that interest of learners in chemical education has been decreasing in spite of a number of promising schemes such as Chem. Study and Chemical Bond from USA; Nuffield and Salters from England, Science for the 70’s and Alternative Chemistry from Scotland, RicoDiC from France. Johnstone (2000) also reported some problems in chemistry teaching. Johnstone (2000) stressed to minimize the gap in research and practice. He claimed that by using the modern research findings we can create and increase the interest of students in the learning of scientific concepts. Similarly the problem of interest in occupation can also be solved. It is suggested that the modern research findings might be used to the optimum level to improve classroom situations.

Lopez and Lent (1992) noted that helping students to improve their conceptual understanding has been the problem of science education and classroom teacher /science educators. The problem of conceptual understanding requires a wide array of pedagogies. The importance of scientific enquiry was also recognized by Herbart Spencer. Herbart in 19th century addressed the problem of conceptual understanding and attempted to propose answer to this important question through scientific enquiry. He firmly suggested that students must be made free to investigate and in drawing their inferences from the investigations carried out by them. So, scientific inquiry is not a new one.

Science education is not the name of just content learning; it is in reality more than this. Science must be grasped in the meaning of activity and its dynamism is well recognized. It is an active process of finding solutions to problems and it critically analyses and evaluates the evidences that are related to our micro and macro
cosmos (NRC, 1996) Students are naturally curious about their material world and science education should nurture their intrinsic and inherent innate potential. Science education should help the students to make their thinking scientific and investigative. NRC (1996) envisaged the following essential features of science (a) science is dynamic in nature (b) it gathers and evaluates data (c) seeks for patterns (d) formulates and tests scientific explanations. When the students engage themselves in the scientific investigations, they learn the critical ways of thinking. Making use of this critical thinking develop scientific reasoning skills that enable them to get control over their learning.

The main goal of science educators, curriculum experts and science education has been to find out core and big ideas that can be used to shape and establish our understanding of the subordinate/secondary ideas. The knowledge has been connected by these big ideas. Interrelated and well connected form of knowledge has been point of emphasis for science educators (NRC, 2005). Bruner (1960) strongly suggested that core and central ideas must work as a base for the curriculum. Johnstone (2000) examined the role of big ideas in learning with understanding and found these as a significant contributing factor in learning and understanding. Johnstone suggested to use these big ideas as underlying principles while framing the curriculum. If these core ideas, are not kept in mind while structuring the curriculum learning process will be badly hampered. Understanding of these big ideas makes possible the transfer of learning to novel situations. NRC (2005) commenting on the concept of big ideas expressed that knowledge organization and learning process must go side by side. NRC (2005) further stressed the importance of these underlying principles that lead the learners to conceptual understanding. These are critical to effective educational practice. These underlying principles assign new role to teacher. The teacher has to
assist the learners in the learning process. Conceptual understanding can not occur unless big ideas are grasped. The teacher has to help the learner in chaining the big ideas with the subordinate ideas to bring about the effective linkages. The learners have to see the patterns of linkage of these underlying principles and the way these are applied in their environment.

NRC (2005) suggested that the following fundamental principles should be taken in to account while designing effective learning environments in order to develop deeper conceptual understanding in the students.

1. Making possible use of ideas already present in the minds of learners.

2. Exploiting cognitive links of scientific concepts in the conceptual understanding.

3. Development and use of self-control potentialities

The above cited principles are basic to learning if the basic data regarding the learner is properly utilized. The basic target for the teacher is to move the learner from inexperienced to the expert stage. Bybee (2000) thinks that scientific inquiry can do this function of transformation if acts as a mediator. Because scientific inquiry is manipulation with the environmental objects so science should be understood in the procedural sense and it must underpin the further selection and organization of all sorts of leaning experiences and activities. The process of inquiry must be made obligatory without any discrimination of grade and level. Inquiry provides a sound base for science learning if its processes like questioning, planning, investigating act as appropriate tools and techniques and are put in to practice.

Scientific inquiry engages the learners with the environment and they learn science by doing. Inquiry is playing with material objects and when learners manipulate with the material world they make use of their senses. So the learners
understand their material world. Scientific inquiry helps the learners to grasp the central ideas which are essential for further learning.

National Institute of Science Education (NISE, 1997) concluded that scientific inquiry might perform the following functions:

1. Recognition of central themes rather than their minutiae
2. To develop deeper understanding and sense of big ideas
3. Interrelationship of central ideas and the justification of the relationship.
4. Elaborated and detailed knowledge
5. Ability to reason

NISE found strong relationship between higher and lower ideas. The students being lack of appropriate scientific knowledge may feel difficulty to make subtle difference. Therefore science teacher should help the learners to make the superordinate ideas distinct from subordinate ideas.

NRC (20005) made a successful claim about the relationship between learning with understanding and scientific inquiry. NRC called conceptual understanding and learning an outcome of scientific inquiry. NRC further claimed about the role of factual knowledge in learning with understanding. Factual information is prerequisite to learning a concept with understanding. When learners proceed through procedures they are likely to learn more. Therefore NRC strongly suggested that big ideas be organized and based on activities and competencies.

Zimmerman, and Carlos (1999) investigated the relationship between learning concepts with understanding and student achievement and devised the ways that can contribute to strengthen this significant relationship:

- Increasing the time consumed by students during instructional activities.
- Allocating adequate time to instruction in core concepts.
Minimizing instruction and maximizing learning engagement time, so the learning time can be extended.

NRC (1996) examined the relationship between learning and doing. NRC found that students learn science better when they do something or perform an activity. Science is not a pile of fragmented concepts and theories but it is way to construct knowledge, a method, a method of thinking and investigating a world around in which we live. Here scientific inquiry comes to help us by acting in a dual manner i.e. methodological as well instrumental to form the concepts and link these concepts with each other in a meaningful way. Scientific inquiry needs to be given such a significant role to accomplish the goal of meaningful and effective learning. This important and crucial role of inquiry has been stressed by different eminent organizations such as AAAS, NSTA and NRC because scientific inquiry is an important and driving factor of meaningful learning and due to this it has significant place in worldwide policy documents and recommendations.

The focus of scientific inquiry is to create good science. Excellence lies is at the heart of good science. Occupational excellence is central objective of good science and it also demands professional excellence. National Council of Teachers of Mathematics (NCTM, 2000) found that profound learning of scientific concepts and principles is the precondition of effective and efficient science. In order to achieve the objectives of good science the standards were developed by AAAS (1993) and NRC (1996).

Teaching Standard E: Teachers of science should learn and promote the scientific inquiry, develop groups that learn and are prone to mutual communication. The good teaching also needs the attitudes, beliefs and social values that are for
inquiry teaching and learning. In order to accomplish this standard the teachers should:

A. Accept, express and demand diversity of all kinds i.e. diversity of ideas, competencies and experiences showed by all students.

B. Make the students responsible of their own learning and ensure their freedom in decision making.

C. Foster and cultivate team work and cooperation among the students.

D. Structure situations that facilitate and promote learning and understanding of scientific concepts. For this purpose large scale discussions might be arranged and utilized to understand principles and big scientific ideas.

E. Imbibe the values and competencies of scientific inquiry NRC (1996).

AAAS (1989) made significant attempts in order to achieve the objectives of good science and sketched out the following principles that underpin good teaching for good science.

- Arrange those activities that ensure active involvement of students.
- The base of inquiry is valid and authentic evidences and stress must be given on the ways of collecting and using these evidences.
- Provide knowledge of procedures and methods that play a key role in the evolution of scientific concepts and principles.
- Put emphasis on methods and means of efficient delivery and communication.
- As science is a social and collaborative activity it is not personal effort therefore ensure the use of team work.
- Do not separate knowledge from finding out
- Learning with meaning is more important than mere memorization therefore always discourage to memorize scientific terms.
Always encourage thirst for knowledge
Always encourage questioning because it supports and favors the ongoing learning. Train the students to formulate the good questions.
There is dire need to discourage the nonscientific beliefs
As aesthetic sense helps to enjoy the nature therefore this sense need to be promoted. American Association for the Advancement of Science (AAAS,1989)

The relationship between scientific inquiry and teacher’s pedagogical content knowledge has been widely investigated (Windschitl, 2004; Roehrig and Luft, 2004). Shulman (1987) identified certain major contributing factors that formulate a strong scientific knowledge base for teachers. These include subject matter content, pedagogical content, general pedagogy, understanding of learners, educational aims and curriculum. Elmore (1996) calls conceptual learning as the core of educational practice. Elmore gave considerable importance to different attributes of teachers that may assist learners in conceptual learning such as way of perceiving nature, students, teachers, their roles in teaching and learning. Elmore further reported that meaningful science learning requires a radical change in the core of educational practice. Ketelhut (2010) identified that teacher’s poor pedagogical content knowledge was a major obstacle in the way of scientific inquiry. If the teacher is poor in subject content matter and pedagogical content then his students will lack both subject matter and knowledge of procedures. But unfortunately only subject matter has been over emphasized and not inquiry.

Keeping in view the established relationship between teacher’s PCK and student learning, teacher professional development has gained much attention in recent years (Nelson, 2008; Henze, et al., 2008; Lee and Luft, 2008; Loughran, et al.,
Teacher professional development has been measured in terms of PCK i.e. pedagogical content knowledge. Sherz, et al. reported that subject specific knowledge and instructional techniques were used as a basis for teacher categorization. Different international comparative studies such as TIMSS and PISA, indicated that a strong background in acquiring core and unifying ideas is prerequisite and mandatory. The studies also identified certain problems that were related to student’s attitudes towards learning. Organization for Economic Cooperation and Development (OECD, 2007) examined the relationship between teacher’s PCK and student’s scientific reasoning skills. A well-known example of this is Estonian students who performed low in questions involving scientific reasoning and recognition of problems. It was concluded that lack of adequate PCK level of teachers and students inquiry skills lead to poor scientific reasoning skills. This empirical study makes clear teacher’s PCK is quite valuable and affects student’s scientific reasoning skills. Laius, Anne, et al., (2009) reported that teacher’s professional development particularly in scientific knowledge promotes students inquiry, reasoning and creative skills. They further reported that teacher’s own competence to carry out inquiry-based teaching is essential to make the environment inquiry oriented. The teacher needs to conceptualize the basic philosophy of the inquiry approach. Rannikmae (2001) found that the teacher ownership is a prerequisite if we want to initiate the change. The changes having instilled by the teacher are more viable and everlasting. Rannikmae strongly suggested that periodical interventions for the development of reasoning skills and inquiry skills be provided to the in service teachers.

Scientific inquiry is near to nature because the students learn more and easily when they are in areal life situations. They manipulate and interact with the real world objects. When they play with nature they “learn by doing”. Inquiry as a way of
knowing, investigating and reasoning has been challenged by Millar (2010). Millar argued that the following factors may act in a negative manner and make the inquiry inefficient.

   a. Lack of preciseness and accuracy owing to student’s naiveness and low quality equipment
   b. Students fail to maintain alignment between data and explanation
   c. The students may conceptualize that answers to the problems under study are already known by the teacher. Thus the whole exercise may lose its benefits due to this preconception. They may think that the whole exercise is baseless and useless.

2.6 Scientific Teaching

NRC (1996) envisaged the complexities and the intricacies of science teaching that are indispensible part of science education and are also envisioned in the standards. The standards act as yardstick to assess the achievements as perceived by the standards. These also set criteria to evaluate teacher’s performance. NRC (2002) emphasized to rectify the prevailing misconception that science education is an aggregate of scientific ideas and concepts and a form of scientific knowledge. It is the active process of finding solutions to problems carrying importance and developing the critical thinking and reasoning about the evidences related to material world. The process of active learning is combination of both the activities that involve doing and things that are done within their minds. Standards identified an important condition that learning occurs when activities are done by the students. As, science primarily rests on the premise i.e. “learning by doing” so science teaching must arrange investigations and provide opportunities to the students so that are in the situations
that are helpful in building the knowledge. Science teaching should make possible the student-teacher and student-student interaction. The students should seek and establish connections between their current knowledge and knowledge from other sources. NRC (2002) identified an important tool i.e. when students act in their environments; they learn better and construct knowledge more actively and efficiently.

NRC (2002) identified that scientific teaching is basically inquiry oriented, investigative, and student-centered and its primary focus is on the growth of cognitive networks of the student. The teacher’s focus is to help and facilitate the students to grasp the development of knowledge as a process. The teacher also focuses to design such classroom activities and assignments that revolve around the scientific maxim of “learning by doing”. The teacher along with monitoring lets the students create their own mental models. To achieve the objective of knowledge building the teacher makes:

1. teaching learning materials
2. relevance of the instructional strategies and the materials
3. knowledge of how students learn

To make the teaching and learning process active, inquiry-oriented and scientific NRC (1996) devised certain standards and criteria for the science teaching so that the teachers arrange and organize effective and active teaching and learning environments. The teaching standards portrayed are:

A. The teacher should design and plan those activities that help inquiry in nature and train the students to perform these activities in the spirit of inquiry.

B. The teacher must act as a guide and facilitator and he/she avoid directions and prescriptions.
C. Learning and assessment must go side by side in order to provide balance to the teaching learning process. The teachers should assess the students periodically in order to refine and revisit the existing shortcomings and bring about fruitful changes in running programs.

D. The teacher should be an efficient manager and should design and arrange situations and resources that are supportive in learning.

E. As science is a collective human endeavor and this needs to be emphasized. Teachers should develop science learner communities; promote the attitudes and values in this regard.

Carnegie Foundation (2010) investigated the role of quality questions and explanations in deep learning and revealed that quality questions and explanations contribute to deep learning. Carnegie Foundation devised the following ways that can contribute to good science.

- Transform classroom into a learning community
- Adopt a playful approach to experimentation (inquiry experiments)
- Scientific discourse i.e. talking and arguing about science.
- Explanations and questions that reflect understanding.

Several studies threw light on the role of real teaching and claimed that real teaching always prone to the demands of the students and the goals. It makes possible the active participation of learners as well as teachers. The teacher believes that learning is the result of doing and the best learning is accentuated when the students act on the material things and engage in active learning. When the students learn by doing they deal with observation and concepts rather than facts and terms and they change the classroom into a learning community that is supportive to learning (Fraser, 1986; Chickering and Gamson, 1987; McDermott, et al., 1994; McKeachie, 1994; Tobin et
The essence of scientific teaching is contextual learning that is the base of understanding and helps to connect the superordinate and subordinate ideas.

NRC (2005) claimed that main focus of effective teaching is sense making and meaning making rather than mere memorizing scientific facts. It also focuses to develop their diverse abilities and the ways they internalize the new concepts by differentiating the new and the existing knowledge. This conceptual understanding provides basics for the application of problem solving.

NRC (2005) made another significant claim that there was no reliable evidence regarding the universal superiority of any teaching method. All teaching methods work differently and differentially in different situations. So, all teaching methods are differential and relative in nature. There is need to analyze the situation and plan accordingly. NRC succeeded to formulate certain principles that underpin science learning and ease the learning situations:

- Ways of thinking are significant and vital for learning of scientific concepts thus these ways need to be made scientific.
- Teach students the methods so that they manage and regulate their ongoing learning. Their active involvement is vital to learning.
- Strong conceptual linkages are basic to learning with understanding and students should be helped in this regard.
- Encourage discussions among students and manage group activities.
- Plan and manage diverse and varied ways of learning that are targeted on conceptual understanding.
- Periodical and intermittent assessment of student understanding that encompasses the whole teaching learning process.
- Make use of multiple ways of teaching and learning.
• Develop the scientific habits of mind.
• Pursuing knowledge.
• Taking a critical stance.
• Working in multiple ways.
• Taking multiple perspectives.
• Acquiring dispositions.
• Engaging in social action.
• Making connections.

Philip (1986) identifies two prevalent notions of teaching:

1. Knowledge reproduction without meaningful understanding

2. Knowledge transformation i.e. building up of knowledge with the help of valid and valued evidences

Jackson (1992) noted that first notion treats knowledge as a commodity and transferable in nature. When teachers, treat knowledge, as a commodity i.e. only to be transferred to the students. Then students are tested whether that knowledge is reproduced meaningfully or not.

Driver, Asoko, Leach, Mortimer and Scott (1994) conducted a study and revealed that the constructivist perspective disagree with the knowledge as a commodity. The constructivist perspective disclosed the flaws, deficiencies and shortcomings that are affiliated with the transmission perspective and bitterly opposed the prevalent view.

In contrast to transmission perspective, when teachers take knowledge as something that is constructed by the students, teacher facilitates the knowledge construction by utilizing varied strategies. He takes in to account the student’s prior conceptions to build on more knowledge. The teacher helps the students to bridge the
prior and the new understanding. The teacher creates more and more learning experiences and opportunities for the students. Alternate ways are used to assess the students learning in spite of traditional assessment. It can also be called as purposeful teaching. Knowledge construction by using the past and present experiences is also known as constructivism which has been widely advocated by Bruner (1990) Kelly (1955) Piaget (1969) Von Glaserfeld (1993) and Vyogotsky (1978).

Philip (1986) says that teaching is nothing alone but it is related to learning and is reciprocal. If teaching is taken to be as commodity then there must a buyer. If there is no buyer then the commodity is useless. In this concept the teacher acts as a teller and ignores the basic principles of how people learn. This approach does not take in to account the basic structures and principles that underpin the teaching learning process. Jackson puts great emphasis on the teaching and learning.

Nemser,Sharon Feiman, et al., (1989) indicated the following three contextual factors that influence teaching and learning process.

A. Purpose of schooling.

B. The ways classrooms are organized.

C. The hidden curriculum.

Schools are reflection of the society and the teaching learning process must revolve around the societal expectations. The above stated factors are learning environments which are essential for effective teaching and learning and also conceptual understanding. Liang and Gabel (2005) reported that higher conceptual understanding demands consistency between the learning preferences of the learners and the real learning situations. They are of the view that any mismatch between preferred and actual learning environment may lead to poor conceptual understanding and negative attitude towards learning.
American Educational Research Association (AERA, 2005) investigated the elements that make teaching conducive to learning and leave positive effect on student learning and achievement. Important factors that contribute to student achievement as noted by AERA are:

A. What teachers learn i.e. pedagogical content knowledge of the teachers and especially the knowledge of student thinking.

B. Time span devoted for pedagogical content knowledge.

C. Aligning curriculum and training with the actual teacher work experiences.

D. Providing more opportunities to understand student learning.

E. Reliable evaluation system aimed at evaluating teacher’s professional development.

Good teachers are crucial to good teaching. The most desirous thing is professional development of the teachers. To achieve this significant and crucial objective, resources need to be utilized. The most important investment is the professional development of teachers. No single method is a universal remedy for all educational problems. The teaching learning situation is a matter of diversity and demands a wide array of teaching learning methods and needs periodical professional development of teachers. While highlighting the importance of science, scientific inquiry and teaching for understanding, NRC (1996) stated that science has become a central activity and there is dire need for active inquiry. The critical importance of teaching for learning with understanding has increased many fold.

Recently Centre for Research on Education, Diversity and Excellence (2010) investigated the prevailing teaching learning situations and attempted to reformulate the principles that make the teaching, instruction and learning more fruitful and
productive. These principles intend to maximize the instruction by taking into account and improving the following conditions of instruction.

a. Making teaching and learning a joint effort of teacher and student.
b. Connecting teaching learning situations to real world problems.
c. By developing language and literacy.
d. Cognitively challenging activities that advance student’s learning and understanding.

2.7 Science Teaching and Practical Work

National Commission on Excellence in Education (NCEE, 1983) set out a study to unveil the prevailing state of teaching, instruction, and science education. The Commission envisaged a framework to cure this dismal state. In order to reform high school science education, the Commission provided these insights (a) effective introduction of the scientific concepts, laws, procedural concepts of the physical sciences and life sciences; (b) the ways of finding the solutions to problems in the light of inquiry and logical thinking; (c) the way the scientific concepts, rules and principles are applied (d) multifaceted implications and consequences. In the light of the aforementioned findings, revision of science courses was recommended.

National Commission on Excellence in Education (1983) provides a future line of action and goals of science education. The report puts too much emphasis on the basic concepts, laws and principles which are the basic requirements of scientific literacy. The basic concepts are basic requirements for deeper learning and understanding. The study emphasized the ways, the basic concepts and principles which are learned. The report also advocated for the scientific inquiry. The evidence from this study suggests exploiting the application aspect of the constructed scientific
knowledge. NRC (2005) set out a study to investigate the role of scientific concepts and principles. The study clearly established the role of scientific concepts and principles in scientific literacy. The study verified the importance of scientific concepts and principles in learning. The report explicitly claimed that understanding of basic concepts and laws of science make us informed citizens and also helps us in making wise decisions. NCEE indicated the weaknesses in the way of acquiring the scientific concepts and their applicability in the society. The basic concerns shown by the report were also confirmed by the assessment reports by National Assessment of Educational Progress. “The Nation’s Report Card” also gave stagnant scores of students from 1969 to 1999. NAEP established a strong link between the scores and ways of acquiring scientific concepts. It was decided with consensus by the educators and scientists that the situation owes to the weaknesses in basic understanding in scientific concepts and laws. Reforming and revamping school science education was a matter of concern. The educators, scientists and curriculum specialists put their heads together to look into the cause of the said weaknesses. Hofstein and Namaan (2007) revealed that practical work has a central role in the learning of concepts and learning the ideas with understanding. They further revealed that as the practical work is deep-rooted in the principle of “learning by performance”, so hence it has a number of potential benefits. The assertions regarding practical work made by Hofstein and Namaan (2007) are consistent with the views of NRC (1996, 2000 & AAAS, 1990). Tobin (1990) investigated the role of laboratory in the construction of knowledge and found that working in laboratory significantly contributes to (i) construct knowledge and enhances the learning of ideas with understanding and in interlinking these ideas. Laboratory activities not only verify the present knowledge but also pave the way for forwarding the knowledge. He also suggested that practical work maximizes the
meaningful learning if the students find and really exploit the opportunities of doing science. Hodson (1993) pointed out certain weaknesses in the practical work and its utility. He suggested that clear goals must be set before making use of practical work. He criticized the practical work and its utility and suggested that clear and vivid goals must be set before making use of practical work. Reid and Shah (2007) hold the view that practical work is basic to all sciences at all levels. They claimed that practical work and practical work is substantive to all science courses and practical work should be the substantial part of each and every science course. Keeping in view the nature of chemistry, they recommended making the practical work a necessary component of chemistry courses at all levels. Reid and Shah (2007) pointed out weaknesses in the utilization of time devoted for practical work. They suggested for proper utilization of allocated and available time. There must be clear alignment between course objectives and the activities performed to achieve these objectives. The students must not lose the motivation and stimulation. There should be clear and vivid alignment between course objectives and the activities used to achieve these objectives. Reid and Shah (2007) think that chemistry content and practical work are inseparable. Nakhleh, et al. (2002) claimed that practical work is at the heart of secondary school chemistry lessons. Practical work has over encompassing nature i.e. content as well as methods are to be learned. (Blosser, 1983) Another significant aspect of practical work was shown by Duschl, (1990) He claimed that practical work is an important tool to understand the nature of science. Many researches conducted in the field of practical work indicated that only inclusion of practical work is not sufficient for achieving the intended objectives. (Lunetta, 1998; Nakhleh, et al., 2002).More recently, literature has emerged that offers contradictory findings about the effectiveness of practical work as stated by Bates (1978) Gunstone and

a. Fail to link purpose of investigation and the design of experiment
b. Fail to link earlier and later experiment
c. Failing to conceptualize their own conceptual inconsistencies, their peers and the scientist’s community.
d. Failing to grasp the essence of practical work i.e. practical work as playing with instruments or playing with ideas.

A number of studies have reported that the above mentioned weaknesses can give rise to complete failure of practical work. These are the studies by Tamir and Lunetta, (1981) and Tobin (1990). They further suggested that practical work should not be a cookbook. In order to make it a meaningful practice, they recommended bringing about radical changes in the nature of practical work at school level. As present mode of practical work is not up to the mark and lacks potential to meet the standards and shoulder the responsibilities imposed by the scientific and technological literacy and preparing the students vertically within the disciplines. Therefore, it needs to be made more inquiry-oriented as it helps the students to gain learning with understanding of scientific concepts and principles and their application in their daily life. These are the studies by Hofstein and Lunetta, (1982) Gunstone and Champagne (1990). Similarly keeping in view the significance and importance of practical work Lunetta (1998) proposed that there is dire need to link practical work with content in meaningful context. The need of community of learners was strongly felt and recognized by Lunetta (1998). Similarly NRC (2005) recognized the significance of community of learners and promotion of practical work. NRC further revealed that
community of learners is indispensable to inquiry mode and creates useful conceptual structures that are essential for meaningful learning. The study under discussion confirms the previous evidences regarding the effectiveness of community of learners and contributes additional evidence in favor of community of learners in student achievement, gain excellence in competencies and growth of scientific predispositions like the scientists at work.

Bennett (2008) examined the effectiveness of practical work and reported the advantages that accrue from the practical work i.e. motivation, independence, reflection, retention and more group dynamics. Bennett (2008) conducted a survey in order to analyze the prevailing composition of practical work and reported the following findings:

- 2% of the activities could be described as really experimental.
- 37% of the activities related to knowledge verification.
- 53% of the activities were related to investigative skills.
- 8% related to divergent activities.

From this analysis Bennett (2008) reached at the conclusion that students were found missing the real essence of discovery aspect of practical work in chemistry and were going through the meaningless exercise.

Johnstone (1997) offered contradictory findings about the effectiveness of practical work and reported that practical work was a source of information overload particularly when highly structured. The students have to follow strictly provided instructions. They fail to achieve the data interpretation skills which are the real essence of science teaching and learning. In order to enhance the effectiveness of practical work Jonstone suggested that while designing and planning practical work,
information processing capacity and ways of student learning might be properly addressed.

Bennett and O’Neale (1998) examined the role of practical work in “teaching learning process” and reported certain weaknesses of the practical work such as, time consumption and the recurrent expenses. They argue that if practical work succeeds to achieve the intended objectives then expenses make no matter.

Bannet (2008) views practical work a recipe unlike the views of Tamir and Lunetta (1981) Tobin (1990). As recipe practical work was well structured and predetermined by the teacher and the teaching assistants, Kelly and Finlayson (2007) supported the recipe type practical work because it was highly structured and predetermined. The intended objectives were quite clear and students performed the practical and learnt from the teacher as well as from each other and so the chances of wastage were minimized. They also reached at the conclusion that this sort of practical work was helpful for attitude development. They also suggested that recipe type practical work might be made more beneficial with certain appropriate modifications. As it is evident that practical work has to deal with tasks, therefore Garratt (2002) suggested certain points that might be taken into account when getting it into the task.

- Identify and understand the nature of the question
- Type of evidences leading to the answer.
- Ways to develop situations favorable for the evidences.
- Devise ways to evaluate processes and evidences
- Making decisions to move forward.

Johnstone and Al-Shuaili, (2002) while commenting on the suggestions made by Garrett stated that these are legal responsibilities of teacher as well as the teaching
assistant. They further added that if these are done with modification by the student with the sense of ownership then these are much fruitful in connecting the previous and present experiences. If these elements are taken into account with thoughtful skills these will provide dependable and reliable paths directed towards the scientific solutions. It means that student’s involvement in the practical work makes it more effective and conducive to learning with understanding. Tan (2004) reported that practical work encourages the active involvement of the learners and helps to develop the sense of ownership in the learners.

Bannet (2008) explored the level of structure and recipe in practical work. He revealed that student has recipe with him for the practical work but differs on account of ownership. Bannet suggested several courses of action but specifically he recommended that practical work needs to be made available and initiated from the early stage to get maximum benefits. More time must be allocated for the practical work so as to get maximum retention. Bannet proposed for the reduction of some curricular load because practical work is time consuming activity.

Bailey (2008) while comparing the student-centered and teacher-centered teaching methods identified certain demands of the practical work teaching style:

a. Management skills to handle complex environment.

b. Well understanding of chemical concepts.

c. Excellence to design and conduct experiments that are challenging and accessible to learner.

d. Attention to detail.

The development of wide range of skills i.e. process, manipulation and investigation are at the heart of the practical work. Garratt (1997) and Bennett and O’Neale (1998) uncovered varied competencies that are central to laboratory work.
Figure 2.6. Competencies learning with the help of laboratory source

<table>
<thead>
<tr>
<th>Competency</th>
<th>Source</th>
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<tbody>
<tr>
<td>Procedural competencies</td>
<td>Garratt (1997)</td>
</tr>
<tr>
<td>Management and manipulation</td>
<td>Bennett and O’Neale (1998)</td>
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<tr>
<td>Confidence to conduct experiments</td>
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<tr>
<td>Overall knowledge of laboratory</td>
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<tr>
<td>Careful examination competencies</td>
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<tr>
<td>Keen observation</td>
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<tr>
<td>Knowledgeable of safeguard devices</td>
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<tr>
<td>Procedures of the experiment</td>
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<tr>
<td>Recording competencies</td>
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<tr>
<td>Data compilation</td>
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<tr>
<td>Data processing</td>
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<tr>
<td>Techniques to analyze data</td>
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<tr>
<td>Draw results from data</td>
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<tr>
<td>Analysis of observations</td>
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<tr>
<td>Skillful presentation</td>
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<tr>
<td>Application of scientific concepts</td>
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<tr>
<td>Writing a research report</td>
<td></td>
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<tr>
<td>Collaboration and cooperation</td>
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<tr>
<td>Skillful communication</td>
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<td>Communication and coordination</td>
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</table>


There are certain similarities in the skills reported. The above mentioned skills are the outcomes of the practical work and attribute to the student-centered approach unlike the traditional one (Kelly & Finlayson, 2007). They found practical work more effective if assisted with critical elements such as collaborative group efforts, conversational support, practical activities, meaningful assessment methods, textual and imagery presentations. They also found that unlike traditional practical work problem based practical work is more helpful for concept learning and skill development. They also found that students pass through the whole science process when dealing with the problem based practical work. Several studies investigating practical work have highlighted factors such as complexity and ambiguity that might hinder in the attainment of goals of practical work and instruction. This difficulty can be solved by providing detailed procedures.

### 2.7.1 Goals of Practical Work

Practical work draws on the notion of “learning by doing”. NRC (2005) uncovered the current substantive weaknesses that stigmatize the school science education and strongly suggested to reframe the goals of school science in order to encounter and face problems of 21st century. The goals aimed at filling the gap between theory and practice. NRC suggested following courses of actions in order to minimize the gap in theory and practice and for the achievement of goals of 21st century.

1. deeper understanding of subject specific knowledge and content;
2. developing and fostering scientific reasoning abilities;
3. making clearer understandability of experiential knowledge and work;
4. promoting and fostering the competencies regarding experimentation
5. understanding the ways and means that science uses to solve the problems
6. Nurturing and promoting student’s interest in science and developing collaborative spirit and abilities.

NRC (2005) pointed out that traditional practical work is not the sole solution to each and every problem but suggested to make use of a wide array of instructional strategies for the deeper learning of fundamental concepts and principles. NRC (2004) reported that multiple teaching methods are at the heart of good science and are a source of multiple opportunities to achieve the standards. Multiple strategies help teachers to capture the student’s interests, provide bridge to fill the gap in content areas, and contribute to deeper conceptual understanding and scientific inquiry.
and Shah (2007) identified that the practical work may have different aims. NRC found that laboratory experiences can only be helpful in attaining learning goals if:

1. focus on clear consequences,
2. embedded in classroom instruction,
3. well integration with subject matter and process, and
4. properly evaluated

### 2.7.2 Nature of Practical Work

Nature of practical work in high school science has been under debate since 1900s. Glenn (2004) states, “Science is an organized body of knowledge and a method of proceeding to an extension of this knowledge by hypothesis and experiment”. It is the basic and prime function of practical work to diversify the devices of science that will encompass the knowledge to student’s life time. As scientific knowledge is well tested, developed with consensus by a scientific community and is above any dispute, knowledge undergoes construction and transmission simultaneously. Practical work plays an important role in the construction as well as transmission of knowledge. Millar (2010) argues that there are two broad categories of “teaching and learning” according to the nature of function i.e. transmission and transformative. He thinks that role of practical work at school level is transmission of knowledge rather than discovery or construction of new ideas. At school level, practical work just performs the function of ownership; the students just own the already established and agreed body of knowledge. This mode is just collective in nature and the students just collect the scattered pieces of information which has negligible rate of transferability. This teaching learning situation simply confirms and verifies the already existing undisputed body of knowledge. So, practical work as a transmission mode is recipe in
nature because its outcomes are known ahead of time. So, transmission mode minimizes the active role of student in the design, planning and investigation of activities. The students are not encouraged to engage and pursue their inquiries.

The second viewpoint is that the practical work might be transformative in nature. It should be a combination of hands-on science and an inquiry. The teacher might have designs and plans to encourage and support students so that they can construct their own meanings. This lies close to the scientific view according to Millar (2010).

Science educators view practical work at the heart of good education rather than rote and meaningless learning because the practical work touches upon the student’s abilities, and learning with understanding. The students easily accumulate the facts and find and develop connections through the sense impressions. The skills such as learning, inferring, judging and verifying are easily developed through observation and experiment. Such investigations strongly favor the meaning making and understanding rather than fragmented learning and memorization. The material learned would be retained for longer period and the student will become an independent learner (BSCS, 2007).

2.8 Science of Learning

How to define learning? It has been a perplexing question. Different schools of thought define it in different perspectives. Learning has different aspects, angles, usages and contexts in different disciplines and it is defined accordingly. Therefore, it is difficult to define learning precisely, consistently and in interdisciplinary perspective. The interdisciplinary definition may be precise and consistent. The psychological perspective sees learning as a change in efficiency and performance
and the use of cognitive processes may be conscious or unconscious. The use of cognitive processes must promote problem solving and performance in the daily life functions. This view not only suggests but also stresses to connect learning and thinking. Cognition is an important ingredient of this definition. The use of cognitive processes will result in more efficient and effective learning. Educationists relate learning to action. They think that learning is the product and outcome of action. The educational perspective has two concerns about learning i.e. acquisition and expansion of knowledge and change in action patterns and capabilities. Biological perspective view learning, a cerebral process, where brain reacts to stimuli by involving the perception, processing and integrating the information. This perspective sees learning as a change that results due to the connections between the neurons. The connections among the neurons produce and support the cognitive processes. Learning is highly dependent on the patterns of interconnectivity and the different ways by which different neurons connect with each other at the same time as well as integrated circuits of neurons. The durable and lifelong learning is the result of strong interconnections of the neurons. The poor learning is the result of poor or weak inter-neuron connections. The strength of learning also depends on the number of neurons (OECD, 2007).

The effective and efficient learning demands that the teacher should be well versed with the structure and function of neuron, the way they generate new connections and also the way the connections get weakened. The brain is an aggregate as well as an activity of neurons. The understanding of human brain also carries significant importance for the teacher because the internal functions of brain are highly dependent on the type of stimuli that are presented to the learner during the teaching learning process. The brain receives the stimuli from the environment and
then processes it and makes this factual knowledge the integrated part of the permanent useful knowledge. This is the ultimate goal of education.

Johnstone (2000) claimed that concept formation highly depends on senses. The sensors perceive the materials. Therefore the teacher should take in account while planning the instruction. The teacher should make the concepts concrete that are abstract in nature. Johnstone advocated for the use of concrete illustrations and non-illustrations mode and emphasized to initiate from the macro level while teaching. He also suggested that the pre-learning of the students should be taken into account. At macro level the students recognize the materials in their environment and form the concepts directly. At macro level the students receive the stimuli through the sense organs, process these stimuli and make it part of their permanent memory. The learners when interact with the stimuli are in a good position to make these stimuli the useful part of their existing knowledge. The significant objective of meaningful knowledge can be achieved through practical work. Johnstone further revealed that the abstract concepts such as element, compound, atom, chemical reactions, electrons and bonding, need to be treated at macro level. The treating of these concepts at macro level may ease and strengthen neural paths within the brain of learners. Several studies investigating role of macro aspect in learning (Albanese & Vicentini, 1997; Chi, 2005 and Lee et al, 1993) showed that middle school learner’s thought processes highly depend on macro representations which relates their direct experiences with matter. They further added that macro representations are more outcome-oriented with younger students and help them to learn with understanding. Laboratory is a good vehicle for the said purpose. OECD (2007) following biological perspective of learning found that meaningful and lasting learning occurs when connections among
neurons are strengthened. Poor or weak learning occurs as a result of weak connections among neurons within the brain.

Johnstone, (2000) observed the nature of non-concrete and non observable concepts and made a firm claim that these concepts have been creating difficulties for students. These non-concrete and abstract concepts need to coincide with the psychological demands of learners. The non-concrete concepts fall in the sub micro part of Johnstone model and need to be made concrete by different strategies such as concrete models of atoms, molecules and chemical reactions by role playing. Johnstone revealed that arrangements must be made to learn those concepts which can not be learned directly. The non-concrete concepts must be brought to the tangible and macro level so that the students can see, feel and observe the phenomenon with their senses. Johnstone (2000) conceptualized that if chemistry content is organized and sequenced according to the way students learn, the difficulties of students are likely to be reduced. Learning can be enhanced and made more meaningful by appropriate content sequencing, coinciding curricular sequencing with learning styles of learners and their capacity to learn. Chemistry as a subject full of non-concrete content and subject specific language that is too dense. The teacher should be aware of all these difficulties while teaching the subject of chemistry.

Johnstone (2000) identified and warned against the troubles that can result from simultaneous presentation of three forms of concepts when teaching chemistry because these concepts possess different nature i.e. physical, nonconcrete and symbolic. The immediate and simultaneous introduction of chemistry content to the learner not only poses failure to the learning process but also the teaching process. There is a lot of content in chemistry which may find absence of pre-learning within the thoughts of the learner; the new content will find no attachments in the neural
webs of the learner. In case of misalliance, there will be no new neural networks hence the learning will be rejected. To solve this problem the teacher should find the prior learning and its level by different types of diagnostic tests. Johnstone (1997, 1999, and 2000) investigated certain content of chemistry and found that it has been a source of difficulty for students. He found that the difficulties were due to varied form of concepts of chemistry and the student’s diverse ways of learning. He also revealed another critical factor that significantly affects the instructional process i.e. the working memory capacity of learners. The simultaneous working at three levels in chemistry may collapse the working memory and the information to be learned will be rejected and there will be no learning. As the students are not experts they can not hold such a large bulk of information instantaneously.

Figure 2.7. Lessening of thinking ability due to lack of first or native language

Available thinking area / Working space

Reversing

Translating

Adapted from Johnstone and Selepeng, (2001). Chemistry Education Research and Practice in Europe.
Johnstone and Selepeng,(2001) suggested that teaching learning process would have been much more effective if the teacher is aware of the following facts:

- how to sequence the curriculum/content ordering
- the way students learn
- ability to process and hold information.

After 1950s learning has undergone revolutionary changes which owe to experimental tools, research methods and novel ways to interpret data. There was wide array of techniques that had eased the understanding of functions of mind. Cognitive science has primary role to revolutionize and refine the concept of learning by utilizing the multidisciplinary approaches. In the embryonic stage learning was confined to rote learning and memorization while thinking and reasoning were out of its domain. Now it is a well established fact that rote learning is not a true learning. Learning is characterized with understanding. The basic character and spirit of learning is learning with understanding. Learning is not to learn the fragmented pieces of information. So the concept of learning has undergone a considerable change. The primitive curricula were purely rooted in the learning by rote rather than concept formation. The change in the facets of learning owes to new science of learning that discourages the rote learning. Cognitive science stresses and advocates for learning with understanding.

Knowledge of facts is prerequisite to learning. Therefore, it leads to learning with understanding. The facts must be gained with understanding and knowledge of facts must support thinking (NRC, 2000).The facts gained by rote learning result in the failure of learning with understanding. NRC (1999) recognized that prior knowledge, context, language and social processes play a significant role in the cognitive development and learning. According to Glaser (1994) and NRC (1999)
effective learning demands draws on four critical principles that fabricate effective learning environment.

1. Learner-centered environments
2. Knowledge centered environment
3. Assessment to support learning
4. Community-centered environment

2.8.1 Learning and Existing Knowledge

Johnstone (2000) investigated the role of existing knowledge in learning and recommended to find that knowledge, that is familiar to the students, is part of their knowledge storage. So, to start in a traditional way is not helpful for learning with understanding. Johnstone and Otis (2006) and Schmidt (1983) suggested to use problem based learning to activate the prior learning. They described that problem based learning acts as an activator and raises the level of familiarity of the learner while learning. The focus of problem based learning is elaboration of existing knowledge and the learner begins with the knowledge already he knows. The questions that learner generates in the light of prior knowledge helps to understand the chemical phenomenon. It can be inferred from this argumentation that problem based learning can be used as a facilitator in the learning of concepts. They further claim that problem based learning is complementary in nature and enhances the learner’s interest in learning.

Learning science is not an independent discipline but rather it is a combination of knowledge obtained in several specialties and now it has become an interdisciplinary field. While discussing the conditions under which “learning with understanding” takes place, OECD (2008) reported existing knowledge as an
important contributing factor. Reflection or metacognition was also found another factor necessary for deeper conceptual learning to take place.

It always remained central to learning science research to improve the learning science environment i.e. science classrooms, laboratories and even schools that give rise to in depth learning.

OECD (2008) recommended to design learning environments according to the following model.

- Provide learning experiences according to the needs of the learners
- Diversified learning sources and diversified learning experiences. Learners should not be confined to the classrooms, laboratory and school. The students should get benefit from internet, museums, factories, hands-on learning experiences etc.
- Learning should be considered collaborative effort. The learners should form learning communities.

A number of studies have found that science is a joint effort, both on a local and on global scale. Research in the field of chemistry is usually carried out in groups. Collaboration is a basic and central element of the nature of science (McComas and Olson 1998, Osborne, et al.; Aksela and Vesterinen, 2009).

OECD (2008) recommended the following measures in order to improve learning.

- Curriculum should be framed, designed and based on modern theories of learning and diagnosing the misconceptions that are part of the learner’s cognitive structures.
- A teacher having adequate pedagogical content knowledge, all modern trends and knowledge of contemporary researches.
Assessment measuring in depth learning not measuring rote learning.

Simms (2006) addresses the problem of rote learning and terms it as surface learning because knowledge gained in this way is in the form of fragmented bits of information. Knowledge gained in this manner is not transferable and convertible and can not be used in other desired situations. The surface learning lacks reflection, meta-cognition and understanding. The students just intend to complete the course requirements.

Entwistle (2000) identifies the other side of the continuum i.e. learning with understanding or deep learning. Here the students intend to connect the present knowledge with the existing or previous knowledge. The knowledge gained in this way is termed as useful because it can be applied in novel and strange situations for solving problems. This type of knowledge has reflection, metacognition and understanding.

Constructivist theories of learning view learning as interactive process. Vygotsky holds view that learning takes place by interacting with others and interaction scaffolds learning. Learning from others acts as an important tool to fill the gap and make the learner more knowledgeable (Mujis, 2007).

McCune (1998) while commenting on both categories of learning offers contradictory findings and finds that both the categories do not take in account the individual ways of learning. He further reports that learners often associate memorization with understanding. This approach has two benefits i.e. memorization assists understanding and helps learners to enhance the academic scores. It is also found the memorization when associated with understanding; the efficiency of memorization is enhanced particularly for examination purpose.
Entwistle (2000) also reports that the product of deep learning is learning of rules, principles, laws or problem solving. Learning of principles requires active involvement and engagement of learners or “learning by doing”. Learning with understanding requires that the learner be put in the actual learning situation and should actively involve in the situation.

The objective of gaining useful knowledge that can be used by the learner other than formal settings can only be achieved if suitable learning environment is created. The antecedents visualized for learning of higher order cognitive skills are:

- Actively taking part of the learner in learning situations
- “Learning by doing”
- Group effort as a way of learning (AAAS, 1993)

Simons and Bolhuis (2004) witness a shift in the teaching and learning paradigm and claim that learning with understanding or conceptual development is the ultimate goal of the teaching learning process otherwise the knowledge gained becomes useless and carries no utility if following points are ignored. They demand the following ingredients of effective teaching learning process:

- Thinking as a scientist, actively learning and self regulation
- “Learning by doing” as a learning principle, active involvement in the learning situation, learning from the classmates
- independent learning

As the world is rapidly changing and the demands of the changing world are increasing day by day, continuous revision and renewal of the required skills enable to deal with the instant technological changes.

NRC (2000) investigated the relationship between learning and active involvement of learners in learning situations. NRC strongly disagreed with the
receptive and passive concept leaning and found a positive correlation between
learning and active mental processes. NRC reached at the following key points that
contribute to make learning meaningful.

- the initial knowledge of the students
- Use of initial knowledge, stored in the permanent memory of learners. Initial
  knowledge held by the learners has great significance for integration of old
  and new knowledge. The gap between former and later ideas is harmful for the
  learning of scientific concepts. The teacher needs to bring to the surface ideas
  that lie within the neural webs of learners with the help of examples and non-
  examples. The student’s initial ideas are loosely connected or some may be
disconnected or may be in fragmented form. The teacher should help the
learner to strengthen connections and join the ideas that are solitary in nature.
The ideas presented to the learners must be relevant to the ideas stored in the
permanent memory. The teacher’s job is to detect the level of difference
between the pre-ideas and the post-ideas held by learner and then fill the gap
accordingly and design the conditions and activities that prone to meaningful
learning.
- Strong foundation of subject specific knowledge has great importance for
  further concept formation. The knowledge gained should be easily accessed
  and brought to the conscious level for further thinking and problem solving.
The teacher should help the students to structure their knowledge in such a
way that can be easily traced and got back from the established neural
networks by simple clues. The teacher should help the students to form the
memory pegs in their minds and the knowledge hooked can easily be
unhooked. The bond formation in chemistry needs to be exemplified by a
marriage and love story of two individuals. Love serves to bring the two individuals closer to each other otherwise the situation may be different.

- Effective organization of knowledge leads to greater applicability and problem solving. If knowledge structure is coherent consequently it can easily be used by the learners in entirely different and novel situations. Effective and efficient transferability of knowledge is central to science teaching.

- The students should be able to regulate their learning, thinking and understanding processes. The teacher should help the learners to take control of their thinking.

Ausubel (1978) put great emphasis on prior knowledge and devised different useful strategies to make use of this important influential factor for the meaningful learning or learning with understanding. The prior knowledge is learner’s property that might be readily available to the learner at any time. The knowledge to be gained can be easily chained with the readily available pool of knowledge. The prior knowledge that is any time available to the learner for future relevance is called cognitive structure. The knowledge that integrates in to the existing knowledge network becomes permanent part of memory. The knowledge that fails to become part of the held pool of information gets rejected.

Johnstone (1997) investigated the relationship between working memory and learning and found that information load on the working memory can be lessened by improving the information selection procedures. The prior learning helps the perception filter to work efficiently and if improves the way of information storage as conceptualized by Ausubel (1968). Therefore taking in to account the prior knowledge, and its efficient use, NRC (2000) noted that the knowledge that the students bring to learning situation must be considered and used in order to create
meaningful patterns of knowledge. The learners bring different knowledge into the learning situations, therefore the teaching learning situations should be designed according to the needs of the learners. Reid (2008) found that use of prior learning is very effective for practical work especially for science teaching. The role of previous knowledge to produce better quality of concept understanding was also investigated by Johnstone, et al. (1994) and was found helpful for future learning. Reid (2008) noted the use of prior learning in school classrooms in question and recapitulation format. Prior learning serves as filter and prevents the working memory to be overloaded and as a result the understanding is enhanced. The learners store the incoming information in a well organized and linked fashion that can be easily recalled and retrieved.

While discussing the differential effectiveness of different techniques which bring about effective learning conclude that we can not say which technique works best. Each and every technique is unique in its effectiveness. NRC (2000) suggested that the selection of the techniques to maximize learning should have alliance with the learning situations. The selection of the technique should be relative to the task. NRC further noted and reveals that experiential activities enrich the growth of the knowledge and underpins the student’s competencies of generalizations from the learned scientific concepts.

Learning is age related and capacity to learn grows with respect to cognitive development. The capacity to process information also progresses with cognitive development (Johnstone et al., 1997; Johnstone & Selepeng, 2001). The thinking ability means to hold and process information efficiency. Learners having greater thinking ability perform better than the learners having lesser thinking ability (Reid, 2008). It implies that the methods applied by the learners to learn have significant
impact on instructional process. The modern research findings indicate that while designing the syllabi, the working memory capacity and filtering capacity of the learners must be taken into account seriously. NRC (2000) found that learning should be grounded in the following facts:

- Teaching should be designed in accordance with the learner’s prior knowledge, skills and attitudes. It means that the learner should be understood in detail so that the teaching learning process is improved.
- Student’s involvement and engagement in the tasks is necessary to develop understanding. It has been verified by a number of researches that learning occurs when the learners involve in the learning situation.
- Assessment is an important factor that contributes to optimum learning. If the assessment is understanding oriented then it is useful in developing organized and well linked knowledge in the minds of the learners.
- Situations, practices, activities and contexts help students to understand concepts. The learners can not own the ideas and concepts unless they involve themselves in the learning situations. Students in their different cognitive stages such as concrete operational and formal operational stages demand different activities, practices and situations that help them to give meaning to concepts, rules and laws that are otherwise difficult to comprehend. Keeping in view this important factor that efficiently contribute to learning, context-based curricula were introduced i.e. chemistry in the community (Chemcom), Salters chemistry, chemistry in the contexts (CIC) and Chemie im Kontext (ChiK). De Jong (2006) indicated that Contexts have inherent potential to illustrate concepts that are especially helpful in understanding abstract concepts because contexts are application oriented and inspire the learners to
apply their knowledge. The contexts also help learners to change their concepts in situations accordingly.

NRC (2000) views learning not a solitary endeavor but collaborative in nature. The students might communicate with each other in a collaborative manner and find solutions to the problems and build the knowledge to achieve the common goal. It can be further said that learning can not occur in isolation but its real essence lies in involvement, engagement and manipulating with the environment. Learning can not take place outside real life situations but real life situations provide impetus to learning.

2.9 Language of Chemistry

According to Vollmer et al. (2007), language is an important prerequisite and tool to develop and construct conceptual knowledge. Language is basic to cognitive operations and putting the learners in situations that are learning oriented. Language also acts as a facilitating element in the construction and learning of subject terminology. Language has two areas i.e. language of the subject and language for learning. Extensive research efforts have successfully noted that language other than mother tongue causes problem in the learning of science (Cassels & Johnstone, 1978, 1980, 1983, 1985). Technical language of science was found to be a matter of concern. It was also indicated that familiar words when used in unfamiliar way are also a source of confusion and hinder learning. Second language as a mediator was also found to be a big obstacle in the way of learning. As the second language is less familiar to the learners, therefore it undermines the potential of the learners to learn effectively and efficiently. Therefore learners have to heavily rely on the rote learning.
Cassels and Johnstone (1985) studied the effect of mother tongue and non-mother tongue on the learners and found that the learners having mother tongue outperformed those having non-mother tongue. It means learners feel ease when they express and communicate in their mother tongue.

Cassels and Jonstone (1985) also noted that the poor performance of second language learners was due to lack of knowledge of sentence structure. The first language learners perform well because they are exposed to real life situations and they learn formally as well as informally. They understand the use of different words in different contexts, different situations and in varied backgrounds. Cassels and Johnstone (1985) revealed and listed different words that had different meanings in different contexts and learners specifically unfamiliar with unfamiliar contexts felt difficulty.

2.9.1 Second Language and Reasoning

Cassels and Johnstone (1985) indicated that second language learners were not good at grammatical knowledge and felt difficulty to apply the rules of grammar and could not get control of their learning and failed to get ability to chunk the given text in the language that was not their mother tongue. As a result the second language learners failed to understand the meanings of the words used in the text. Similar claim was made by NRC (1997). Reading difficulty was attributed to lack of access to meanings. Therefore the learners could not comprehend the text and opted rote learning and the objective of meaningful learning was not achieved. To make the learning successful learners, prior knowledge and skills, suitable for the scientific literacy were of high value for the learning process (Johnstone & Selepeng, 2000; NRC, 1997). The unfamiliarity of the learners with the mediating language also badly
affected the reasoning ability of the second language learners. Poor knowledge of the mediating language badly affects the communicative exchange and expression ability.

Lewis (2007b) revealed that if students were provided with conversational perspective, easily learnt the scientific concepts. She emphasized to find the gap between the knowledge held by the students and scientific concepts. The learner’s subject specific ideas and language specific ideas must be taken in to account. Language could play a key role to fill the gap between learner’s pre-learning and the concepts of science. Lewis further urged and stressed to devise the instructional devices that could be helpful for bridging the gap as identified by her. She pointed out that “talking science to existence” was a good strategy to solve the problems of unfamiliar language.

Johnstone and Selepeng (2000) claimed that language affects the information filtration process. The incoming information was controlled by the prior set of experiences or the knowledge already present in the long term memory. The knowledge known by the learner served to select the learning. The filtered information entered the conscious part of the memory where it was processed, reordered and rearranged to make it part of long term memory and link it with the long term memory. In case of unimportant or improper linking it is rejected or forgotten. Johnstone and Selepeng (2000) reported that working memory capacity also posed some limitations on learning. The unfamiliar language overburdened the conscious part of memory and processing capacity decreased. On the other hand over processing minimized information holding capacity and learning was badly affected. The students having mother tongue other than English overburdened the working memory when they translated English text in to their mother tongue. Much of the available space gets occupied by the over processing and overload.
Johnstone and Selepeng (2000) witness a remarkable decrease in the working memory space as the learners shift from familiar to unfamiliar language and in certain cases the working memory capacity touches the zero value. They also find a strong association between working memory space and reasoning ability. Unfamiliar information that is not relevant to the prior neural networks, fails to create further cognitive structures and hampers strengthening and reorganization of existing linkages. Unfamiliar language takes longer time to process. In case of unfamiliarity, learner has to depend on rote learning, which is not meaningful and permanent and can not be used in problem solving and is likely to be forgotten. Johnstone and Selepeng (2000) conclude that unfamiliar language is a problem of second language learners because they have to learn science in a strange environment i.e. language that is unaccustomed to them. They suggest that problem can be solved by using the first language or by improving the conditions for learning language.

Vollmer (2006) firmly indicates that language is a matter of school education and strongly recommends to understand its importance. In order to improve language Vollmer strongly suggests taking in to account the following points of significance.

- Broadened and purposeful use of language needs to be improved throughout the school education
- Learning can not develop if not contextualized. The learners may be provided relevant activities, experiences such as talking, writing and speaking.
- Language is first step towards the development of mental networks that contributes to the attainment of meaningful learning.

Vollmer (2006) also establishes a close link between language and thinking. Language development is an important prerequisite for thinking and reasoning. He makes a firm claim that language and learning are closely linked. Language is
connected and associated with learning and learning absolutely fails without proper language development. Language is not only a concern for mother tongue only but it is to support conceptual development and makes learning meaningful. An important goal of language is to enable learner to think clearly, communicate clearly and express clearly as per subject specific demands. He further suggests that language needs to be used across the curriculum i.e. beyond any conventional confinement. He emphasizes to use language as a tool for:

- Learning content, concepts, rules in different subjects
- Enabling the learners to develop public discourse abilities
- Think and reason explicitly
- Applying language abilities to think, express, reflect, write, speak and communicate clearly
- Conceptualizing and understand subject specific knowledge or subject terminology
- Integrating subject terminology and academic knowledge

Subject specific knowledge can not be learned without language. The basic educational tasks such as perception, observation, concept formation and communication are entirely dependent on language competencies. Language efficiently forms the basis for all sorts of cognitive functions. It is a fact that the language specific goals must be aligned with subject specific goals.

Language of chemistry is really a challenge not only for educators but also for the learners (Reid & Mbajiorgu., 2006; Johnstone & Selepeng, 2000). Language of chemistry is highly specific and has specific content nature. Every day language and discourse comprises 2-3 words per clause but chemistry has 10-13 words per clause. This increase in words per clause increases the density of the chemistry language. At
the same time chemistry works at three levels and specifically it works at micro level which is absolutely abstract. The factors namely, language and abstract level are the problems in learning chemistry. Abstract nature of the content or topics cause misconceptions or systematic errors made by the students (Kousthana & Tsaparlis, 2002). The abstract level/non-observable level hinders understanding of chemical concepts and is the main source of misunderstanding and ambiguities (Reid & Mbajiorgu, 2006). They further indicate that chemistry mostly works on non-concrete level but with semantic representation. This basic level of chemistry demands great care so that misconceptions may be avoided. Baker (2000) indicated certain basic and elementary concepts of chemistry such as matter, substance, element, compound and solutions which are not only difficult to teach but also to conceptualize by the students. He recommends that these concepts must be defined in macroscopic terms. These basic concepts need to be defined in precise manner; the definitions might not give the unobservable and non-concrete outlook. So Johnstone (1999, 2000) disapproved these concepts because of misalliance with the modes of learners to learn. To enhance comprehensibility of concepts of chemistry it might progress from observable to non-observable i.e. from macroscopic to microscopic. Nelson (2002) suggests that teaching chemistry needs to be started from observable level to non-observable level and it needs to conceptualize the microscopic ideas i.e. atomic and subatomic ideas through concrete ideas. He further adds that particle level ideas are difficult to understand.

Vollmer (2007) investigates the relationship between language and learning and reports that language is central to learning as well as understanding. He finds language as a prerequisite for learning subject terminology and vocabulary. Language plays a pivotal role for identifying, naming and linking these concepts to one another
and making the whole cognitive structure. Subject matter knowledge can not be learned in isolation; the language processes play a critical role in the learning of subject matter knowledge. The learning of subject terms owes to language. It means that language plays a foundation role in the development of subject terminology and vocabulary.

Vollmer (2007) reveals that language competencies and skills are necessary for meaningful learning of scientific terminology which is non-linguistic in nature. He further suggests that transferring the language competencies throughout the curriculum is necessary to get the fruitful results. He further suggests of linking up and integrating the competencies and skills attained by the students in the theoretical language and subject matter knowledge. While discussing the role of general academic language and subject specific language, he strongly suggests of using both as a means to organize and structure the knowledge. The integration of language as a subject and subject terminology should develop and refine the discourse functions. He further points out that general academic language should develop certain public discussions and talks functions such as describing, naming, comparing, and narrating and even some more complex linguistic functions. The integration of linguistic and nonlinguistic skills must enable the students to express orally and in writing. The students should be able to communicate the scientific knowledge they gained with understanding. He identifies five basic communication skills that help to promote knowledge. He further adds that knowledge and understandings are meaningless without communicative ability.

When the students encounter a phenomenon, the students need to interpret it not only to others but also to themselves. But this objective can only be achieved by subject specific knowledge and subject specific language. A chemical phenomenon
emerges due to a number of factors which need to be analyzed, judged and understood. The prerequisites that contribute to the understanding of phenomenon and the relationships among these are:

- The basics of subject specific language of chemistry
- Precise and accurate application of the subject specific language
- Exchange of information with peers
- Argumentation and counter argumentation in subject specific terminology
- Using communication as a tool, explain the observed phenomena and exchange it with others in different formats such as verbal, symbolic and mathematical.

Carrasquillo and Rodriguez (2002) explain the linguistic difficulties of the teachers while they are teaching science through English. They find that science is, in itself, a language and he suggests to treat different science disciplines (biology, physics, and chemistry) as a separate language. It means that chemistry must be treated both a language as well as an organized body of content. Keeping in view the dual nature of chemistry, it needs to be taught as a form of content as well as a form of language.

In order to improve learning in chemistry Kelly (2010) developed a language hierarchy for any chemistry classroom.

- Subject-specific language/chemistry terminology e.g. noun phrases such as hydrochloric acid or the process of neutralization
- General academic language might be cross-curricular in nature and not specific for any subject. It is more useful for procedural knowledge.
- Peripheral/secondary language, it does not follow certain rules and is easygoing in nature and its main purposes are (i) communication between the
students (ii) communication between the students and the teacher to manage classroom as well as laboratory.

If students intend to learn chemistry then subject terminology is a prerequisite. Kelly identifies that when the students are learning chemistry as an additional language they need to be given:

- Longer time be given for general academic language in chemistry
- Provide more revision and practice
- Teachers need to adjust their ways of teaching as per learner styles and subject demands.
- As chemistry language is alien to the learners, concepts formation needs more time to formulate in formal language and students be allowed to express the content in their own words and back to subject specific language.

Coxhead (2010) identifies common words in general academic English. These are of special interest to teach chemistry terminology. The main target of chemistry teaching is to teach chemistry content and this objective can only be achieved if learner variables in terms of language, concepts and procedures are taken in to account (Ball, 2008)

Kelly (2009) examined the relationship between learning and subject specific knowledge and listed three aspects that contribute to learning in chemistry. These three aspects are:

- Linguistic
- Conceptual
- Procedural

Kelly (2010) claims that following learning experiences can play a pivotal role for the promotion of language of chemistry:
- Imagery to facilitate acoustic stimuli
- Textual material
- Conversational support by peer discourse and peer conversations
- Useful word lists
- Models to provide real life experiences
- Chemistry terminology through unit word maps that indicate logical linkages

Keeping in view that language of chemistry needs to support learning of chemistry, contextual elements are of special interest i.e. conversational support, action recipes, imagery and pictorial representations that can boost the learning.

Research efforts prove that imagery, pictorial representations and audiovisual aids of the materials, maximize learning within minimum time and also drill efforts have key role in this regard (Hilgard & Bowers, 2004). Similarly Clegg (1999) identifies that content learning needs to be supported by conversational efforts, imagery, and pictorial representation of the material to be learned. He urges the need to give the words the pictorial representation and need to be made concrete. Hilgard, and Bowers (2004) reveal that when words are transformed in to images, easily link up to the existing concepts and make the learning meaningful. The learning based on images is more lasting. They further suggest of making the language and words explicit by pictures and graphical representations and suggest that content be given diagrammatical representation.

NRC (1997) claims that second language acquisition can be improved by conversational support, face to face talk and practice in talk. It was also the finding that contextualized tasks are more effective than the less contextualized tasks. The second learners learn more efficiently and effectively when they are in face to face
situation. NRC (1997) finds another important factor i.e. interaction with peers and teachers contributes to the second language learners. Linguistic environment is more conducive to learning specifically for language learning. The relevant classroom features that are helpful for language learning are:

- Face to face communication around visible referents
- Using simple syntax
- Providing many drills and paraphrases
- Speaking slowly and clearly
- Checking comprehension and understanding
- Expansion and extending topics

According to Vollmer (2006), use of language across the curriculum is needed. He recommends to give equal importance to language throughout the curriculum. He suggests extending the language competencies and skills. The language might aim at conceptual literacy and discourse skills. The language aims at developing clear thinking and clear communicating abilities in relevant concepts. He further suggests of using the language as a tool to conceptualize content and knowledge and to integrate the conceptual and expressive abilities of the students.

Kelly (2010) demands to revisit and re-examine the ways, teachers are prepared for teaching chemistry when they are teaching the learners learning through English as a second language. Kelly thinks, “It is a move from subject to the learner and from content to the language of the subject”. He suggests for making chemistry attractive through, language, communication and real life contextualization.

De Jong (2010) reports that context-based curricula tend to perform better than the isolated curricula in teaching learning process. He further reveals that if chemistry
is connected to the personal life of the students, it helps the students to give meanings to concepts, rules and laws.

### 2.10 Sequencing Chemical Knowledge

Morgan et al. (2004) claims that human memory is not an untidy and jumble of unrelated information. The humans keep their information repertoire in order, categorize and classify it in a number of ways.

Taba (1962) gives prime importance to specific facts and factual knowledge in the elementary and secondary stage because these specific facts lead to the fundamental principles and thought systems. Taba thinks that sequence and continuity must contribute to the formation of ideas. Taba stresses two fold sequencing (1) order of complexities and abstractness (2) intellectual rigor or cognitive demand.

Taba (1962) states that sequence is, in essence, a way of making learning continuous, accumulative, effective and efficient. It is actually a step-by-step procedure towards the exercise of higher order cognitive skills. It can be said that it is merely a developmental plan to help the learners to grasp more with understanding, develop metacognitive abilities and independence in thoughtfulness. Learner should exercise control over his learning process. Recently researches have shown an increased interest in sequencing (Reigluth, 1992; Bruner, 1971; Rothkopf, 1971; Skinner, 1978; Greeno & Bjork, 1973). It means that sequencing basically focuses on the experiences that follow each other in a more dynamic and psychologically coherent order. Taba (1962) demands rhythm in the incoming information, organization, synthesis and expression. Any sort of imbalance may overload the memory and may result in failure in the internalization of information. Lack of sequencing has existed as a learning problem for many years.
Curzon (2004) views sequencing as ordering the content as per well defined principles. The main objective of sequencing and ordering the content and objectives is to promote and bring about meaningful learning. The teacher can order the content according to the learner’s prior knowledge and according to his own personal experiences of arranging the learning conditions that are conducive to meaningful learning. He thinks that simple skills might precede the complex ones. The concepts that are simple and easily comprehensible need to be learned before the learning of the advanced or complex concepts. Generalities should precede the specifics. Similarly an overview might come first then the detailed study.

Johnstone (2000) places emphasis on the interest and familiarity. Familiarity means previously learned structures in the student’s memory. Gagne (1978) emphasizes that meaningful context is an essential prerequisite for the learning of the new information. So the instructional designer makes use of the available mental structures of the learners. Similarly NRC (2000) emphasizes to exploit the ways people learn. Gagne (1978) also associates problem solving to the previously learned information and intellectual skills. Relevant information and capabilities are essential for efficient problem solver. Gagne (1978) thinks that sensory information is more important especially visual. Here visual information means that the information that is easily perceivable and observable can be easily related to the large meaningful structures or organized body of knowledge. For better association of newly learned information, the content needs to be ordered from observable to non-observable. For sequencing factual information Gagne (1978) prescribes to make use of prior learning of what Ausubel (1968) called “organizers”. Gagne thinks that memory is a stored and well organized body of knowledge, having verbal relations. The larger bodies of knowledge are organized from smaller units and these smaller units constitute
meaningful wholes that are interconnected well like the periodic table that helps the students to learn, names, symbols, atomic numbers, mass numbers and other properties of large number of elements. The important condition of learning is remembering and retrieval when organized meaningfully (Ausubel, 1968). Gagne (1978) claims that just knowing or remembering is quite inferior to knowing the meaning of something. He emphasizes to know as a concept. Knowing with respect to meaning enables the learners to identify examples and non-examples that act as standards and serve to define and delimit the class. Similarly Johnstone suggests and strongly emphasizes to begin with things that are interesting, familiar and aware. He suggests beginning with macro might support sub-micro. Chemistry mostly works at atomic and molecular level that is not observable and this level creates problems for the learners to conceptualize chemical concepts. Therefore chemical concepts need to be organized from concrete to abstract level.

Tsaparlis (2000) criticizes the traditional modes of content sequencing such as descriptive chemistry and linear approach which fails to address the student’s cognitive development, conceptual difficulties, and relationship of chemistry to technology, environment and the real world situations. He mentions that at lower secondary level, the content needs to be based on educational and psychological grounds. He suggests to make chemistry distinct in to macro, symbolic and sub-micro parts. The sequencing must begin from simple, familiar, concrete, and most observable to abstract ideas. Tsapalis (2000) designs the SOMA (states of matter) approach and content is logically organized i.e. gaseous, liquid and the solid state.

Tsaparlis (2000) further mentions the programs that failed to address the student’s difficulties and levels of understanding and as a reaction new programs were introduced such as Science, Technology, Environment and Society (STES), Chemistry
in Context and Chemistry in Community (ChemCom). These programs attend to the real life situations and attempt to relate chemistry to our daily life problems.

Gagne (1984) while discussing the essentials in the learning of learned capabilities or intellectual skills states that some concepts are simple and some are complex and these need to be distinguished. The learning of any concept depends upon the prior learning of these simple or complex concepts. It can be said that concept formation is highly interdependent and how each higher form of learning depends on the lower form of learning has been summarized by Gagne (1984) as shown in diagram.

*Figure 2.8. Learning hierarchies and their interdependence*

Adapted from Gagne (1984) Interdependence of learned capabilities

Gagne (1978) theorizes that the prime function of instruction is to prepare the learners to solve the problems of their daily life. Learning and intellectual development are highly interrelated. Intellectual development simply begins from observation i.e. from the simpler ones, to the complex ones such as rule learning and
problem solving. Gagne (1978) summarizes the hierarchy of intellectual skills as under:

*Figure 2.9. Hierarchies of intellectual skills*

- Problem solving (Higher order rules)
- Require as prerequisites
- Rules
- Defined concepts
- Require as prerequisites
- Concrete concepts
- Require as prerequisites
- Discriminations

Adapted from Gagne (1978) hierarchy of intellectual skills.

This sequence explicitly shows that learning needs to begin with concrete experiences and then lead toward abstractions.
CHAPTER 3

RESEARCH METHODOLOGY AND PROCEDURE

The present study was designed to determine the comparative effectiveness of traditional method of instruction and Johnstone’s three-cycle instructional method in teaching chemistry to class ninth students in urban area schools of Islamabad district.

The experiment designed took 22 weeks for completion. The experiment started on the first day of class of school year 2010-11 i.e. April 2010 to January 2011 in chemistry classrooms and science laboratory of Federal Government Boys Model School F-8/3 Islamabad.

The structural and procedural organization of the experiment was described as under:

1. Population
2. Sample
3. Contents of the study
4. Time table
5. Study design
6. Measurement procedures (construction, validation and improvement).
7. Data gathering and data analysis procedure.
8. Johnstone’s three-cycle instructional method/aspects of learning/chemistry triangle
9. Traditional instructional method
3.1 Population of the Study

There were fifteen boys’ secondary schools in the urban area of district Islamabad during the school year 2010-11. All the schools had the essential requirements for the teaching of chemistry:

- Science learners
- Well established and well equipped science laboratory
- Science teachers
- Laboratory staff

The target population for this work included the male secondary school science students of Islamabad city school year 2010-11.

3.2 Sample of the Study

Out of the fifteen institutions, one institution i.e. Federal Government Boys Model School F-8/3 was randomly selected for experiment.

The record of all the students who were promoted to ninth class was obtained from the examination in charge of the school. All the students who were promoted to class ninth were taken as sample for the experiment. The achievement scores of the students in the eighths class science in the annual examination 2010 served as baseline data. The scores of the students were given descending rank order. On the basis of eighths class science achievement, the students were matched and randomized. The matched randomization was used to make two equivalent groups i.e. experimental and control on even odd principle. The sampling roadmap is given as under:

Islamabad district → from 15 boys schools randomized one sample school → three 8th class sections → 120 students promoted from class eighths to class ninth →
3.3 Contents/Domain of the Work

The contents of the experiment were divided into two parts:

✓ Theory
✓ Practical work

The theory domain included, ninth class chemistry textbook, published by the Punjab textbook Board, Lahore. The practical work domain consisted of practicals listed in National Curriculum for Chemistry 2000 and placed at annexure j.

3.3.1 Practical Course for Ninth Class as Recommended by National Curriculum 2000

There were ten practicals recommended for ninth class secondary science students by the National Curriculum 2000 and are placed at annexure j.

3.4 Time Frame of the Study

The study lasted for 22 weeks of the school year 2010-11 in the chemistry classroom and science laboratory of Federal Government Boys Model School F-8/3 Islamabad. The treatment was given for six days per week. Per day duration of the treatment was forty minutes. The time duration was equal in both the groups. The teachers of both the groups had equal academic and professional qualifications i.e. B.Sc., M.Ed.
The students visited the chemistry laboratory once a week for two period’s i.e. 80 minutes. A prelab of thirty minutes in the form of lecture was introduced one day before the commencement of actual practical work. The prelabs highlighted the essential ideas and concepts related to the experimental work to make the learning more meaningful in the subject of chemistry as envisaged by Johnstone. The experiment schedule was harmonized and integrated with the overall time frame of the institution.

3.5 Research Design

Keeping in view the robustness and ability to minimize and control the threats to experimental validity the posttest only equivalent group design was used for this study.

The study had two groups i.e. experimental group and control group. The objective of equivalence was achieved through matching and randomizing. Randomization is a way which ensures equivalence. The baseline data for the purpose of equivalence was obtained from eighth class science achievement promotion examination conducted by the school for the year 2009-10. The experimental condition was set for the experimental group and control condition for the control group.

An exhaustive search of the extant literature (Gay, 2000; Gibbon & Morris 1986; Best, 1999) indicates that the design is effective in controlling threats to experimental validity. It is exactly like the pretest posttest control group design except that no pretest was used. The major worth of the design is that it averts the interference of the pretest. The randomization is also useful and ensures group equivalence. The randomization equates the groups on most of the variables that are
likely to affect the interpretation of the results. Another advantage of the said design is that it provides extra time to the researcher to think over the important changes that might be carried out in the posttest. The randomization when used in juxtaposition with control group enhances the effectiveness of the design and serves to check almost all sources that make the work internally invalid except loss/dropout. Gay (2000) made another significant claim about the effectiveness of the design and wrote that if there is least chance of differential loss of participants, “the posttest only group design” is very effective.

After viewing and evaluating the design from different angles, the researcher decided to design and conduct the experiment in the light of this design. The symbolic representation of the design is given as under (see figure 3.1).

*Figure 3.1.* Symbolic representation of “posttest only equivalent group design”

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(pre)</td>
<td>R</td>
<td>X</td>
</tr>
<tr>
<td>(Post)</td>
<td>O₁</td>
<td>O₂</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>R</th>
<th>X</th>
<th>O₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>R</td>
<td></td>
<td>O₂</td>
</tr>
</tbody>
</table>

Adapted from Gibbon and Morris (1986) How to design a program evaluation. California: Sage publications. Inc.
Symbols:

“R” = represents randomized

“O” = represents observations

“X” = represents treatment

The graphical and symbolic depiction of the abovementioned design was further made clear and given more elaborative forms (see figure 3.2).

*Figure 3.2. Elaborative form of the sampling and study*

```
Boys in Federal Government Model School
F-8/3

Aged 13-13.5 years

Sampling by randomization and matched ability

Test of significance applied to find any sort of difference between sample 1 and sample 2

No significant difference was found between sample 1 and sample 2 at the onset of the experiment.
```
3.5.1 Variables of the Study

The variables of the study were

3.5.1.1 Independent Variables

The independent variables represented are (see figure 3.4).

<table>
<thead>
<tr>
<th>Johnstone’s three-cycle instructional method</th>
<th>Traditional instructional method</th>
</tr>
</thead>
</table>
3.5.1.2 Dependent Variables

Achievement/performance

3.5.1.3 Techniques Employed to Control Secondary Variables

The experimental situation or treatment may be flawed due to the following variables which might be controlled to make and the results of the study more reliable and generalizable.

*Figure 3.5.* The control techniques applied to control intervening variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nature of control</th>
<th>Technique of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of subjects</td>
<td>Administrative</td>
<td>Only ninth class students studying chemistry participated</td>
</tr>
<tr>
<td>Content of treatment</td>
<td>Administrative</td>
<td>Ninth grade chemistry content</td>
</tr>
<tr>
<td>Physical conditions</td>
<td>Administrative</td>
<td>Experiment was confined to a single school</td>
</tr>
<tr>
<td>Practicing teaches</td>
<td>Administrative</td>
<td>Both the teachers were equally qualified</td>
</tr>
<tr>
<td>Gender</td>
<td>Administrative</td>
<td>The participants of the experiment were only boys</td>
</tr>
<tr>
<td>Size and sample</td>
<td>Administrative</td>
<td>Experimental group and control group obtained by randomization and matching. Each group comprised of 38 students</td>
</tr>
<tr>
<td>Average age</td>
<td>Administrative</td>
<td>Aged 13-13.5 years</td>
</tr>
<tr>
<td>Period of treatment</td>
<td>Administrative</td>
<td>The treatment was administered in school year 2010-11 for 22 weeks</td>
</tr>
<tr>
<td>Type of instruction</td>
<td>Administrative</td>
<td>Johnstone’s three-cycle instructional method Traditional instructional method</td>
</tr>
<tr>
<td>Medium of instruction</td>
<td>Administrative</td>
<td>Blended /Bilingual medium of instruction was used.</td>
</tr>
</tbody>
</table>

Figure 3.5 describes a number of sources that may influence the primary variable. The researcher tried to control and devise techniques to control the
secondary variables that might influence the results of the study. Robinson (1981) reported that randomization is the best control technique for a number of secondary variables. He further revealed that randomization is a technique upon which a number of experimental designs are based. It controls both i.e. internal as well as external sources of invalidity. Ferguson and Takane (1989) also view randomization a best control technique for removing all secondary effects. According to them randomization also controls carry over effects.

3.6 Research Instruments

The researcher developed instruments in order to gather data. The instruments developed were:

A. Posttest theory
B. Posttest practical
C. Macro level achievement test + practical test
D. Sub micro level achievement test + practical test
E. Symbolic level achievement test + practical test
**Figure 3.6.** Instruments designed and administered

<table>
<thead>
<tr>
<th>Posttest theory</th>
<th>Posttest practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum marks 65</td>
<td>Maximum marks 10</td>
</tr>
<tr>
<td>Cognitive demands knowledge, comprehension, application</td>
<td>Cognitive demands knowledge, comprehension, application</td>
</tr>
<tr>
<td>Ten units of ninth class chemistry textbook</td>
<td>Ten practicals recommended and listed in chemistry curriculum 2000.</td>
</tr>
<tr>
<td>Macro level achievement test (20 marks)</td>
<td>Macro level practical test (5 marks)</td>
</tr>
<tr>
<td>Sub micro level achievement test (20 marks)</td>
<td>Sub micro level practical test (5 marks)</td>
</tr>
<tr>
<td>Symbolic level achievement test (20 marks)</td>
<td>Symbolic level practical test (5 marks).</td>
</tr>
<tr>
<td>First traditional assessment test (constructed and administered in traditional mode).Marks 65</td>
<td>First traditional assessment test (constructed and administered in traditional mode).Marks 10.</td>
</tr>
</tbody>
</table>
3.6.1 Instrument Construction and its Procedural Organization

The procedural organization for the construction of the instrument comprised of:

3.6.1.1 Development Phase

The development phase comprised of

3.6.1.1.1 Test Planning Phase

The major steps carried out while planning the test were:

a. Number of items to be included in the test and item format
b. Type of objectives to be measured
c. Item weightage specification
d. Theoretical content to be covered
e. Content of practical work
f. Cognitive demands to be achieved in accordance with the Bloom’s taxonomy
g. A table of specification which is a significant basic tool for designing test was used to plan for the number and kinds of items that were to be used on the test
h. The cognitive demands were used keeping in view the local testing context
i. The concepts for planning and designing the test were also taken into account.

3.6.1.1.2 Writing Phase

The writing phase consisted of the following steps:

The diagrammatic representation of the two-way grid was drawn
- Cognitive demands were placed on the top of the table
- Content covered were placed on the left
- The degree of specificity within the content areas was determined by the researcher
- The items were written according to the cognitive demands such as knowledge, comprehension and application.
- Keeping in view the local context, development level of the examinees and nature of the subjects, the researcher tried to make the items more cogent and valid so that the students easily demonstrate the competencies and concepts they possess.
- Keeping in view the question of what, and to enhance the validity, the competent people of the field and the supervisor were consulted to seek their opinions about the test items.
- The opinions and suggestions of the competent people of the field were recorded and in alliance with these expert suggestions selected items were revised and improved.
- The contents of the items were taken from the ninth class chemistry textbook published by the Punjab textbook Board Lahore.
- The items were also reviewed by the other subject teachers at the same grade level for the purpose of improvement and refinement. It was also noted that how well the items matched the objectives. This type of quality control check was very useful because the working teachers were teaching with the same objectives (Wierisma & Jurs 1990). They also noted some benefits of the peer review technique
- Removal of defective and faulty items
- Removal of bias
- Technical flaws and ambiguities

### 3.6.1.1.3 Pilot Testing

Pilot testing has been termed as a high quality control check. It is a significant test developmental procedure and helps to observe deeply the ignored and unheeded areas. It is used to revise and improve the items having any type of flaw and vagueness. Firstly, taking into account expert opinions of the competent people, the items were revised and improved. Later the developed test was administered to a pool of examinees other than the sample selected. After receiving the feedback from the pilot study, the analysis was made. The items were statistically analyzed. The main domains of the statistical analysis were “item difficulty” and “item discrimination”. The difficulty indices and item discrimination power were calculated statistically. The items showing very high difficulty index were revised. Similarly the items having very low difficulty index were also revised. The items having very high and very low discrimination power indices contribute nothing towards discrimination power of the test, therefore such items were revised. The difficulty index and power discrimination index indicate that the respective item needs revision or be discarded. The items should discriminate mastery and non mastery.

### 3.6.1.1.4 Administration of the Instrument

After bringing the basic changes in the research instruments these were administered to the selected sample. After administration, the instruments were scored and kept in record for further use.
3.6.2 The Validity of the Research Instrument

The researcher designed the instruments according to the decided specifications but other authentic ways were used to enhance and make the measurement procedures more valid in the view of the content validity. The test items were analyzed and revised by:

- Competent people/content matter experts of chemistry having expertise in pedagogical content knowledge.
- The validity was also observed by pilot testing.
- Keeping in view the insights and suggestions of the pedagogical content knowledge experts and measures from the pilot study the items/questions/exercises were improved and refined.
- The item’s match with standards of science education and standards of teaching of chemistry were also observed.

3.6.3 Reliability of the Research Instrument

The consistency of the measurement procedures was assessed with the help of split half method (by using Kr 21) and was found to be .90 and .92.

3.7 Traditional Formative Examinations

Along with the research study, the traditional formative examinations were also conducted in order to find out the student’s progress and to evaluate the teaching learning process. These tests were of 75 marks (theory 65 marks & practical 10 marks). These tests were administered to both i.e. experimental and control groups and were entirely according to the traditional examination pattern. The assessment process was also completed as per school examination system. The scores obtained by the
sample 1 and sample 2 were obtained by the researcher and recorded for future statistical operations.

3.8 Statistical Procedures and Analysis

The significant difference between the two means at a selected probability level was calculated with the help of \( t \)-test. The \( t \)-test provides a good comparison between the two means. The \( t \)-test indicates how much larger is the difference between two means if there is no true population difference. As there were two independent samples therefore the researcher used \( t \)-test for the independent samples whether there was any significant difference (.05 level) between the means of the experimental and control group. Data management and analysis was performed using SPSS 19.0 (2011).

3.9 Traditional Instructional Method

Traditional instructional approaches frequently and intentionally follow transmission approach in the chemistry classrooms. In the traditional chemistry classrooms the teachers talk and the students passively receive what is presented to them. In this approach the teacher is considered infallible and her/her authenticity of knowledge is also unchallengeable. The basic notion that reinforces this approach is that the students have no related ideas in their neural networks. In this situation the students are expected to learn without making use of the available neural networks what they have been presented. The students are not encouraged, facilitated and involved in the learning activities and are not given the chance and freedom to describe the situation in their own words. The students are forced to heavily depend on rote learning and ignoring the basic theories and principles of teaching and
learning. The students learn basic facts, formulas, equations and complex concepts of chemistry by heavily depending on memorization.

The teaching of science is not just telling facts and filling the empty vessels. The students accompany with a lot of significant neural networks when they join the school. The teacher must find the different sorts of the neural networks and design the devices that strengthen the significant networks and weaken the unnecessary networks in the learning places. The science standards emphasize to create a situation in which the students are not being told but are being asked. The teaching of science is inclined towards encouraging students to ask their own questions that arise in their mind during the teaching learning process rather than simply asking students questions. The student’s modes of learning are highly influenced by the methods of instruction or the way the teacher teaches them.

The transmission mode of instruction does not allow students to individually formulate the scientific concepts by themselves and the teacher provides the readymade concepts or experiences to the students. The students exclusively depend on the uncontested body of knowledge. When the gap between the scientific ideas and the student’s knowledge is small, the transmission approach is most effective but in case of bigger gap the approach fails to achieve the objective of science learning. The rote learning and memorization is not suitable for learning complex concepts because the students are not involved and engaged in the learning situation. They are just told the facts and fragmented pieces of information. Concept learning involves active learning and self construction of explanation of the phenomena.
### 3.10 Johnstone’s Three-Cycle Instructional Method

Chemistry as a subject is not only based on simple facts but it has also complex concepts. It works at three levels. Chemistry has its own language, facts and complex conceptual knowledge. The knowledge of chemistry has its own intrinsic nature. The modern approaches to teaching and learning are based on entirely different assumptions

- The students are not blank sheets therefore teaching and learning situations and their designing process must make use of diverse learning activities and experiences. The teacher should find the relevant anchorages, attachment areas and hooks of the learners on which the new learned material might be attached
- Avoid the overloading of the working memory of the learners and how the information is processed and the sources that create constraints for the working.
- Teaching of chemistry should take into account the educational and cognitive psychology.
- To solve the problems that are faced by the chemistry classroom and laboratory Johnstone suggested that chemistry teaching and learning should be based on educational and psychological grounds and it should be distinguished in to:

  1. Macroscopic level (easy concept formation by sensible examples and non-examples.

  2. Symbolic level

  3. Submicroscopic level
The aforementioned levels or aspects form a mechanism by using which the learners constructs their knowledge. The bases of the concepts are senses. At macro level we can form concepts directly, easily and sensibly. The things, done in the laboratory and the practical work are a main vehicle for concept formation. At macro level the students frequently make use of observation to form concepts. The macro level learning provides mental scaffolding for the conceptual development. At macro level the students learn fundamental ideas that are used to form concepts. The students must be quite familiar with the examples and non-examples presented i.e. metals, non-metals, and flammable substances. The students should be introduced with the substances that are quite tangible and can be seen, felt, smelt, tasted and observed by our senses.

The students encounter difficulties when they are working at sub micro level. This level demands great care. The students should be provided with concrete learning experiences. The micro cosmos of chemistry deals with atoms, molecules, elements and compounds. All these concepts are abstract and needs to be made concrete. The conversion of abstract ideas to concrete involves constructivist teaching and learning. This constructivist approach further leads to deeper and profound understanding of big as well as subordinate ideas. The attainment of big as well as small ideas is the major objective of the effective teaching and learning.

The third level visualized by Johnstone involves the use of symbols, representations and mathematical formulas.

The important thing that is central and focal to the aspects of learning is to promote profound concept formation by the students. Although chemistry works at three levels is quite different from other disciplines and demands different teaching learning situations. These levels help the learners not only to form concepts but also
to connect different concepts. If the students succeed to understand the central ideas of the subject, they easily connect these ideas and get applied these ideas in the real life situations.

The main functions of the levels of learning are:

- Deeper understanding of the central ideas
- Focusing on the central ideas of the subject
- Relationship among the ideas in a discipline
- Elaboration of the ideas to be learned

*Figure 3.7.* The features of the two teaching methods

<table>
<thead>
<tr>
<th>Group</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration of</td>
<td>According to Pakistani National curriculum</td>
<td>In three cycles:</td>
</tr>
<tr>
<td>educational material</td>
<td></td>
<td>Macro, Sub micro and Representational</td>
</tr>
<tr>
<td>Textbook</td>
<td>Standard Textbook</td>
<td>Re-sequenced textbook as proposed by Johnstone into three cycles</td>
</tr>
<tr>
<td>Practical work</td>
<td>Experiments demonstrated by the teacher</td>
<td>Students performed guided discovery experiments in groups of four</td>
</tr>
<tr>
<td>Chemical notations</td>
<td>Classic(e.g. NaCl, NH₄NO₃, MgSO₄)</td>
<td>Electrical charges in the formulae of inorganic compounds(Na⁺Cl⁻) -parenthesis for molecular groups [e.g.(NH₄)⁺(NO₃⁻), Mg²⁺(SO₄)²⁻]</td>
</tr>
<tr>
<td>Models and analogies</td>
<td>Traditional models discussed in textbook</td>
<td>Drawing and construction of models by students</td>
</tr>
<tr>
<td>Teaching period</td>
<td>22 weeks</td>
<td>22 weeks</td>
</tr>
</tbody>
</table>
CHAPTER 4

ANALYSIS OF DATA AND INTERPRETATION

The study was designed to compare the effectiveness of two teaching methods i.e. Johnstone’s instructional method and traditional instructional method. In order to find effectiveness of the two teaching methods the “posttest only control group design” was used. Ninth class students studying chemistry in the model schools of urban area of Islamabad district comprised of the population of the study. The sampled students were randomly assigned to experimental and control groups. The experimental group was taught through Johnstone’s instructional method and the control group through traditional instructional method. The study was conducted for a period of 22 weeks. During the experiment and at the end of the experiment the instruments used were:

1. Posttest achievement test (theory)
2. Posttest achievement test (practical)
3. Macro level achievement test (theory)
4. Macro level achievement test (practical)
5. Sub micro level achievement test (theory)
6. Sub micro level achievement test (practical)
7. Symbolic level achievement test (theory)
8. Symbolic level achievement test (practical)
9. Traditional theory and practical formative examinations.

Different hypotheses were formulated with respect to different objectives of the study.
Ho: There is no significant difference between the eighth class science achievement scores of experimental and control group before the experiment.

Table 4.1

*Group formation and equalizing on the basis of achievement scores of eighth class science test*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>67.8</td>
<td>15.6</td>
<td>0.3(74)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>68.8</td>
<td>15.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The groups were formed and equated on the basis of eighth class science achievement scores. The sample consisted of 76 ninth grade students studying chemistry. All the students successfully completed the experimental period of 22 weeks.

The *t*-test was used as a means to find whether there was any significant difference between the mean scores of students in the eighth class science achievement test conducted for experimental and control groups. The results showed no significant difference between the mean and S.D. values of the experimental (**M**=68.8, **SD** =15.3) and control group (**M**=67.8, **SD**=15.6), and \( t(74) = 0.28 \). The insignificant mean difference helped in determining that both the groups were equal in eighth class science achievement test before the conduct of experiment. Further clarity is added by the figure 4.1. The subsequent hypothesis is given on page 134.
Figure 4.1. Group formation and equalizing on the basis of eighth class science achievement scores
First Objective

In order to compare the effectiveness of Johnstone’s instructional method and traditional instructional method on the achievement of students in the subject of chemistry, the corresponding null hypothesis formulated was as under:

Ho2 There is no significant difference between the achievement scores of the students in the subject of chemistry (theory) taught through Johnstone’s instructional method and traditional instructional method as measured by the macro level assessment tool.

The test of significance was applied to observe significance of difference between the achievement scores of the students in chemistry theory taught through Johnstone’s instructional method and through traditional instructional method as measured by the macro level assessment instrument.

Table 4.2
Achievement scores of the students in chemistry theory collected through macro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>10.8</td>
<td>1.7</td>
<td>0.28(74)</td>
<td>&lt;.78</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>16.2</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The hypothesis has been supported by the results. The difference has been significant. The result expressed that the mean and S.D. values calculated for Johnstone’s instructional method ($M=16.2$, $SD=1.9$) were considerably greater than the mean and S.D. values calculated for traditional instructional method ($M=10.8$, $SD=1.7$, and $t (74) =2.95$). As the calculated $t$-value (2.95) was considerably greater than the tabulated $t$-value (2.), therefore the above stated hypothesis was rejected.
Hence it was decided that macro level teaching as envisaged by Johnstone helped to enhance the conceptual understanding and meaningful learning of secondary school students in chemistry theory. The results of this study was also verified by the conclusions of Johnstone (1999), Tsaparlis (2000), Tsaparlis and Zarotiadou (2000), Ausubel (1960, 1968). The study was in line with the findings of Johnstone and Otis (2006) as it broke down linearity and compartmentalization tendency in science learning as conceptualized by Pendley et al. (1994), Lee and Fensham, (1996), Herron (1996), Sanger and Greenbowe, (1999).

Table 4.2 presents a clear picture and it has been presented graphically in figure 4.2. The subsequent hypothesis is given on page 137.
Figure 4.2. Data showing the achievement scores of the students in the subject of chemistry (Theory) gathered through macro level assessment tool

![Bar Chart]

- **Control**: Mean Score = 10.8
- **Experimental**: Mean Score = 16.2

Legend:
- Series 1
Ho3 There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the macro level assessment tool.

Table 4.3.

Achievement scores of the students in the subject of chemistry (practical) gathered through macro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>1.7</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>3.6</td>
<td>0.7</td>
<td>12.6(74)</td>
<td>&lt;.000</td>
</tr>
</tbody>
</table>

The test of significance was applied to find the significant difference between the performances of the students in the subject of chemistry (practical) at macro level teaching as visualized by Johnstone. The result indicated that the mean and S.D. values for Johnstone’s instructional method ($M=3.6$ $SD=0.7$) were significantly greater than the mean and S.D. values calculated for traditional instructional method ($M=1.7$, $SD=0.6$, $t (74) =12.6$. As the calculated $t$-value (12.6) was greater than the tabulated $t$-value (2.), therefore the above stated hypothesis “There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the macro level assessment tool” was rejected.

The findings of this study were consistent and in line with the results of Hofstein and Naaman (2007), Reid and Shah (2007) and Donnell, et al. (2007). Therefore this study was helpful in enhancing the learning of science with understanding. The
practical experiences were concrete in nature and made the science concepts sensible and practical to the students because in laboratory they interact with materials to observe and understand the real natural world. Practical work was an important way to learn with understanding and to construct knowledge. Although there was much discussion on the merits of recipe style laboratory teaching method (Meester & Maskill, 1995, Johnstone & Al Shuaili, 2001). On the other hand the opponents claimed that traditional practical work was limited in function i.e. learning. Seery et al. (2007) found problem based practical work more effective than the conventional practical work. Webb and Palincsar (1996) viewed practical work in collaborative sense. They thought that collaboration and team work among low ability learners and high ability learners created effective learning environment. Same findings had been reported by Webb, Nemer, Chizhik, and Sugrue, (1998).

The results of the present study indicated that the experimental group performed better than the control group. Therefore the null hypothesis was rejected. Table 4.3 clearly summarizes the comparative performance of experimental and control groups on macro level achievement but it has been further clarified by the figure 4.3. On page 142 overall comparative performances on macro level achievement test is given. The subsequent hypothesis is given on page 140.
Figure 4.3. Comparative performances of the students in the subject of chemistry (Practical) at macro level achievement test
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at macro level assessment tool.

Table 4.4

Achievement scores of the students in the subject of chemistry (theory + practical) gathered through macro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>12.5</td>
<td>2.2</td>
<td>13.6(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>19.9</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The t-test was used to find the difference between the overall (Theory + Practical) achievement scores of the students in the subject of chemistry taught through Johnstone’s instructional method and the traditional instructional method as measured by the macro level assessment tool. The results indicated that the mean and S.D. values for Johnstone's instructional method (M=19.9, SD=1.9) were significantly greater than the mean and S.D. values calculated for traditional instructional method (M=12.2, SD=2.2, with t(74) =13.6.

It was evident that the mean score of the experimental group (19.9) was greater than that of the control group (12.5). It showed that the difference in the performance was significant and was completely due to the treatment and was not by chance. Therefore the stated hypothesis was rejected.

The outcomes of this study were consistent with the outcomes reported by Chandrasegaran, at el. (2007) and Mahaffe (2005). The results obtained from the analysis are shown in table 4.4. For further illustration and clarity data analyzed was
given graphical form in figure 4.4. The statistical analysis of fifth hypothesis is given on page 143.
Figure 4.4. Comparative achievement scores of the students in the subject of chemistry (Theory + Practical) collected through macro level assessment tool.
There is no significant difference between the achievements scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method at micro level assessment tool.

Table 4.5

Achievement scores of the students in the subject of chemistry (theory) collected through micro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>9.3</td>
<td>1.4</td>
<td>26.2(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>17.1</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The \( t \)-test was used to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method as measured by the micro level assessment tool (Theory). The results indicated that the mean and S.D. values for Johnstone’s instructional method (\( M=17.1 \) \( SD=1.2 \)) were significantly greater than the mean and S.D. values calculated for traditional instructional method (\( M=9.3, SD=1.4 \)) with \( t (74) =26.2 \).

The analysis of data revealed that the mean score of the experimental group (17.1) was greater than the mean of the control group (9.3). Therefore the hypothesis “There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method at micro level assessment tool” was rejected.

The findings of the study were highly consistent with the conclusions of Odubunmi and Balogun (1991), Westbrook and Rogers (1996), Raghurbir (1979),
Hand and Treagust (1991), Novak and Govan, 1984., Novak, 1990). The comparative achievements of experimental and control groups are presented in table 4.5. In order to increase the clarity and insight, the data are presented in figure 4.5. Sixth hypothesis regarding the comparative performance of experiment and control group is given on page 146.
Figure 4.5. Comparative achievement scores of the students in the subject of chemistry (Theory) through micro level assessment tool.
Ho6. There is no significant difference between the achievements scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method at micro level assessment tool.

Table 4.6.

Achievement scores of the students in the subject of chemistry (practical) gathered through micro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>1.8</td>
<td>0.4</td>
<td>17.9(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>3.9</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $t$-test was applied to discover whether there was any significant difference between the achievement scores of students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the micro level assessment tool. The results showed that the mean and S.D. values for the Johnstone’s instructional method ($M=3.9$ $SD=0.6$) were significantly greater than the mean and S.D. values calculated for traditional instructional method ($M=1.8$, $SD=0.6$, and $t(74)=17.9$)

The mean score of the experimental group (3.9) was greater than the mean score of the control group (1.8). It pointed out that the difference in the achievement was significant, and was due to treatment and not by chance. Therefore, the hypothesis formulated above was rejected.

The data made it evident that the pupils taught through Johnstone’s instructional method outperformed the students taught through the traditional instructional method. Some studies indicated that the laboratory experiences lead to more positive attitudes (Renner, Abraham, and Birnie, 1985, Denny and Chennell, 1986). Other studies showed no relation between practical work and attitude (Ato & Wilkinson, 1986; Freedman, 2002). Data presented in the table 4.6 clearly recognizes the role of Johnstone’s instructional method in meaningful learning. Figure 4.6 further clarifies and elaborates the results of the study. The statistical analysis of seventh hypothesis is given on page 149.
Figure 4.6. Comparative achievement scores of the students in the subject of Chemistry (Practical) collected through micro level assessment tool.
Ho7. There is no significant difference between the achievements scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at micro level assessment tool.

Table 4.7.

Achievement scores of the students in the subject of chemistry (theory + practical) collected through micro level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>11.1</td>
<td>1.3</td>
<td>30.1(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>21.1</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The t-test was applied to discover whether there was any significant difference between the overall (Theory + Practical) achievement scores of the students in the subject of chemistry taught through Johnstone instructional method and the traditional instructional method as measured by the micro level assessment tool. The results showed that the mean and S.D. values for the Johnstone instructional method ($M=21.1$, $SD=1.5$) were significantly greater than the mean and S.D. values calculated for traditional instructional method ($M=11.1$, $SD=1.3$, $t(74)=30.1$). It was pointed out that the students taught through Johnstone’s instructional method achieved better than the students taught through traditional instructional method.

Johnstone’s instructional method put emphasis on active and meaningful learning. The students learned better when they were actively engaged in science laboratory activities. Laboratory activities made the science meaningful, understandable and sensible to students. The findings of this study were in line with the findings of Hofstein and Lunetta (1982, 2004), Lunetta et al. (2007), Hofstein et al.
Information presented in the table 4.7 clarifies the role of practical work in concept formation in chemistry. For the purpose of elaboration the data were given the pictorial form in figure 4.7. Data analysis and interpretation of the results of eighth hypothesis has been given on page 152.
Figure 4.7. Comparative achievement scores of the students in the subject of chemistry (Theory + Practical) gathered through micro level tool.
There is no significant difference between the achievements scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method as measured by the symbolic level assessment tool.

**Table 4.8**

_Achievement scores of the students in the subject of chemistry (theory) collected through symbolic level assessment tool_

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>7.7</td>
<td>1.5</td>
<td>22.2(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>15.5</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The *t*-test was applied to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry taught through Johnstone’s instructional method and the traditional instructional method as measured by the symbolic level assessment tool. The results showed that the mean and S.D. values for the Johnstone’s instructional method (*M*=15.5, *SD*=1.4) were significantly greater than the mean and S.D. values calculated for traditional instructional method (*M*=7.7, *SD*=1.4, and *t* (74) =22.2. The results of the study verified the findings of Ausubel (1960, 1968), Karplus (1977), Gabel and Sherwood (1980), Ward and Herron (1980), Philips (1983), Abraham and Renner (1986), Chandran, Treagust and Tobin (1987) and Nurrenbern (2001). Robinson (2003) suggested that the explicit understanding of symbol is obligatory to the students. The learners must be aware of ways of converting a symbol into meaningful information that it represents. Similarly Bodner and Domin (1998) found that distinction between internal representation and external representation is
mandatory and the symbols learned by the learners must have meaning to them because the symbols represent a physical reality. They further stressed that ill conceptualized internal representations may prove problematic. The teacher needs to help the learners to conceptualize these abstract concepts in a right way so that the learners may not develop alternative conceptions. Taber (2001b) stated that alternative conceptions in chemistry might be the result of the way the concepts taught. Taber and Coll (2002) found that failure to represent elements and molecular reactions may encourage students to move towards misconceptions. The results of the study made it clear that thought processes heavily depended on symbolic representation and their role to understand chemical phenomenon could not be denied. Morgan et al. (2004) stated that a symbol represents or stands for some event or an item in the world so images and symbols are used frequently in our thinking. Thinking is a set of cognitive processes that intercede between stimuli and responses. Rappoport and Guy (2008) found that symbolic representation is a way of thinking and is quite helpful in understanding observable phenomenon. They also suggested of replacing the macro mode by symbolic mode. Symbolic and particle micro levels are treated at the same level and contrasted against the macro level as being two extreme levels of thought – observable contrasted with non-observable (Johnstone, 1991; Treagust et al., 2003). As the symbols that are used in thinking are often words and language, therefore thinking needs to be related to the language. As it is evident that symbolic level is also abstract, the teacher needs to deal it with care and take it as a tool to understand the chemical phenomenon.

Table 4.8 clearly shows the role of symbols in learning generally but particularly in meaningful learning of science concepts. In order to make the role of symbols more
clear the data were presented graphically in figure 4.8. The statistical analysis and interpretation of the results of ninth hypothesis has been given on page 156.
Figure 4.8. Comparative achievement scores of the students in the subject of chemistry (Theory) collected through symbolic level assessment tool.
Ho: There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method at symbolic level assessment tool.

Table 4.9.

*Achievement scores of the students in the subject of chemistry (practical) collected through symbolic level assessment tool*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>1.8</td>
<td>.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>3.5</td>
<td>.55</td>
<td>11.4(74)</td>
<td>&lt;.000</td>
</tr>
</tbody>
</table>

The *t*-test was applied to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the symbolic assessment tool. The results showed that the mean and S.D. values for Johnstone’s instructional method (*M*=3.5, *SD*=.55) were significantly greater than the mean and S.D. values calculated for traditional instructional method (*M*=1.8, *SD*=.66, and *t* (74) =11.4.

The mean score of the experimental group (3.5) was larger than the mean score of the control group (1.8), it showed that the difference in the achievement was significant and was due to treatment and not by chance. Therefore, the hypothesis formulated above was rejected. The findings of this study were consistent with the findings of Johnstone (1991, 2000), Barke, (1982), Jones, (1981), Danili and Reid, (2004). In order to show the effects of independent variable on the dependent variable the data are given the tabular arrangements i.e. Table 4.9. For the purpose of further clarity and
improvement the data are given the graphical shape in figure 4.9. The statistical analysis of 10th hypothesis has been given on page 159.
Figure 4.9. Comparative achievement scores of the students in the subject of Chemistry (Practical) collected through symbolic assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at symbolic level assessment tool.

Table 4.10.

Achievement scores of the students in the subject of chemistry (theory + practical) collected through symbolic level assessment tool

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>9.5</td>
<td>2.1</td>
<td>21.1(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>19.0</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $t$-test was applied to find whether there was any significant difference between the overall (Theory + Practical) achievement scores of students in the subject of chemistry taught through Johnstone’s instructional method and traditional instructional method as measured by the symbolic level assessment tool. The results showed that the mean and S.D. values for Johnstone’s instructional method ($M=19.0$ $SD=1.9$) were significantly greater than the mean and S.D. values calculated for traditional instructional method ($M=9.5$, $SD=2.1$, and $t$ (74) =21.1.

The mean score of the experimental group (19.0) was greater than the mean score of the control group (9.5), it showed that there was significant difference in the achievement scores and this difference was due to the treatment and was not by chance. Therefore, the hypothesis formulated above was rejected.

The findings of the study conducted were in line with the findings of previous studies such as Gabel (1998, 1999), Ben-Zvi et al. (1986); Keig and Rubba, (1993),Kozma and Russell, (1997), Tan et al.( 2002),Chou and Chiu( 2004), Wang
Table 4.10 compares the performance of experimental and control groups and shows significant difference between the two groups. For the purpose of further elaboration the data is also given the graphical form in figure 4.10. Statistical analysis of the subsequent hypothesis has been given on page 162.
Figure 4.10. Comparative achievement scores of the students in the subject of chemistry (Theory + Practical) collected through symbolic level assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method at first traditional formative level assessment tool.

Table 4.11.

Achievement scores of the students in the subject of chemistry (theory) collected through first traditional formative level assessment tool.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>22.8</td>
<td>11.8</td>
<td>0.58(74)</td>
<td>&lt;.954</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>22.7</td>
<td>15.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The t-test was applied to find that there was any significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method as measured by the first traditional formative assessment tool. The result showed that the mean and S.D. values for Johnstone’s instructional method (M=22.7 SD=15.7) were not significantly greater than the mean and S.D. values calculated for traditional instructional method (M=22.8, SD=11.8, and t (74) =0.58).

The mean score of the experimental group (22.7) was approximately equal to the mean score of the control group (22.8), it showed that no significant difference was found between experimental and control group. Therefore, the hypothesis formulated above was accepted. The first test was developed and constructed by following the traditional format. The cognitive demands were low. The questions did not adequately measure students understanding (Moore, 1997). Student understanding can only be explained in terms of Ausubel’s continuum between meaningful learning.
and rote learning (Novak & Gowin, 1984). Rote learning can easily be tested through questions having low cognitive demand. The question having low cognitive demand do not stress meaningful learning (Danili & Reid, 2005, Bodner, 1995, Oliver-Hoyo et al. 2004). The questions having high cognitive demand are used to evaluate the cognitive demand of the innovative teaching methods which stress learning with understanding. It means that the ways the questions are asked are highly significant in the assessment of student’s understanding of chemistry. The traditional assessment format heavily emphasize on what than why as evident in the questions asked. Sweller (1994) identified two important factors of information processing that should be taken into account in student assessment (1) nature of the subject being assessed (2) way of designing assessment.

Control group performed equally good with the experimental group because questions set in the test simply relied on recall and memorization. The questions asked just demanded to demonstrate recall and rote learning. As the control group was taught by using the traditional approach that’s why they performed equally good. But as the test items used in the test were based on measuring the conceptual understanding, the experimental group outperformed the control group. Table 4.11 shows no significant difference between the two groups and also shows that the insignificant difference in achievement is due to the effect of traditional examination system. Figure 4.11 further added to clarity. The subsequent hypothesis is given on page 165.
Figure 4.11. Comparative achievement scores of the students in the subject of chemistry (Theory) collected through first traditional formative level assessment tool.
Ho12. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method at first traditional formative level assessment tool.

Table 4.12.

Achievement scores of the students in the subject of chemistry (practical) collected through first traditional formative level assessment tool.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>3.8</td>
<td>1.1</td>
<td>1.41(74)</td>
<td>&lt;.16</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>4.3</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The t-test was applied to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the first traditional formative assessment tool. The result showed that the mean and S.D. values for Johnstone’s instructional method ($M=4.3$, $SD=1.8$) were significantly greater than the mean calculated for traditional instructional method ($M=3.8$, $SD=1.1$, and $t(74)=1.41$).

The mean score of the experimental group (4.3) was slightly greater than the mean score of the control group (3.8), it showed that the difference in the achievement was not significant. As the test construction followed the traditional assessment approach and the student understanding was not the matter of concern. The questions asked did not adequately measure the meaningful learning but only stressed rote learning. According to Entwistle (1992) traditional mode of assessment only checks whether the information transmitted has been received. In constructivist view leaning
means personal knowledge construction and demands that assessment should focus on
depth of knowledge and student learning with understanding (Gipps, 1994). The
constructivist approach views learning in more qualitative than quantitative terms
(Biggs, 1996). Danili and Reid (2006) concluded that assessment format needed to
coincide with the purpose for the use of test. Meaningful learning means learning with
understanding and it demands the similar format of assessment. Danili and Reid
(2005) conclude that essay type questions are more suitable to assess student
understanding and effectiveness of meaningful learning.

The research findings by Barren (1971) and Moore (1973) disagreed with the
above findings and reported that traditional instructional methods were equal in
effectiveness with the constructivist instructional methods. Table 4.12 compares the
effects of independent variables on learning and achievement. Figure 4.12 also adds to
clarity. The subsequent hypothesis is given on page 168.
Figure 4.12. Comparative achievement scores of the students in the subject of Chemistry (Practical) collected through first traditional formative level assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at first traditional formative level assessment tool.

Table 4.13.

Achievement scores of the students in the subject of chemistry (Theory + Practical) collected through first traditional formative level assessment tool.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>26.7</td>
<td>12.8</td>
<td>0.09(74)</td>
<td>&lt;.929</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>27.1</td>
<td>17.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $t$-test was applied to find whether there was any significant difference between the overall (Theory + Practical) achievement scores of the students in the subject of chemistry taught through Johnstone’s instructional method and traditional instructional method as measured by the first traditional formative assessment tool. The result showed that the mean and S.D. values for Johnstone’s instructional method ($M=27.1, SD=17.5$) were significantly greater than the mean and S.D. values calculated for traditional instructional method ($M=26.7, SD=12.8, and \ t(74) =0.09$).

The mean score of experimental group (27.1) was slightly greater than the mean score of the control group (26.7), it showed that the difference in the achievement was not significant. Therefore, the hypothesis formulated above was accepted. The assessment was of traditional nature. The questions asked only intended to measure the knowledge received. The students responses were highly related to the type of question asked. The students recognized the questions asked and formulated the answers according to the question’s format. The questions asked in the test were
only suitable to traditional instructional methods and also more cogent for low cognitive levels. Danili and Reid (2006) concluded that instructional method and assessment must be aligned with each other. On the other hand Goodman (1977) and Carnes (1985) found both instructional methods were equally effective. Recognition and recall can be easily measured by the traditional assessment.

Performance of the experimental group was better than the control group in spite of traditional assessment but no significant difference was observed. It is quite clear that traditional assessment is not adequate for meaningful learning. Hence it left a significant effect on the performance of the experimental group. The questions asked stressed only recall and memorization and qualitative assessment formats were not meant for measuring rote learning. In case of, alternative assessment approach, explicit dichotomy was likely to be observed.

Control group performance was equally effective as because the experimental group because questions asked based on the traditional approach i.e. measuring only the recall and rote learning. As the control group was taught through the traditional instructional method, the way of assessment was in line with the instructional method.

The findings of the study were consistent with the findings of Salman (1977) and Danili and Reid (2006). Table 4.13 shows that both the groups were approximately equal on traditional formative examination and a significant relationship between rote learning and traditional assessment format is observed. Figure 4.13 further elaborates the relationship under discussion. Statistical analysis and explanation of the subsequent hypothesis is given on page 171.
Figure 4.13. Comparative achievement scores of the students in the subject of Chemistry (Theory + Practical) collected through first traditional formative level assessment tool.
Ho. There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method at second traditional formative level assessment tool.

Table 4.14

*Achievement scores of the students in the subject of chemistry (theory) collected through second traditional formative level assessment tool.*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>24.0</td>
<td>10.8</td>
<td>0.24(74)</td>
<td>&lt;.814</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>24.6</td>
<td>13.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The t-test was applied to discover whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and traditional instructional method as measured by the second traditional formative examination tool. The result showed that the mean and S.D. values for Johnstone’s instructional method ($M=24.6$, $SD=13.2$) were not significantly greater than the mean and S.D. values for the traditional instructional method ($M=24.0$, $SD=10.8$, and $t(74)=0.24$).

The mean score of the experimental group (24.6) was larger but was not significantly larger than the mean score of the control group (24.0), it showed that the difference in the achievement was not significant. Therefore, the hypothesis formulated above was accepted. As the second term test was developed in a traditional way, the experimental group performed slightly better than the control group but the difference observed was not significant. The performance of both the groups was approximately equal and was exclusively due to the assessment format.
The traditional instructional method got aligned with the traditional assessment. On the other hand mismatch of instructional method and assessment method in case of experimental group was quite evident and was also revealed by Danili and Reid (2006). One assessment mode was suitable for reception learning whereas the other was suitable for meaningful learning. A clear match was also observed in instructional method and the way of assessment in case of control group. That is why the performance of experimental group remained insignificant. The experimental group learned chemistry concepts with understanding whereas the control group memorized the same.

The findings of the study are in line with the findings of Johnstone (1999, 2000), Danili and Reid (2005, 2006), Ausubel (1960). Table 4.14 presents comparative achievements on second traditional formative examination. Further clarity and insight can be gained from figure 4.14. Subsequent hypothesis along with statistical analysis and explanation is given on page 174.
Figure 4.14. Comparative achievement scores of the students in the subject of Chemistry (Theory) collected through second traditional formative level assessment tool.
Ho15. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method at second traditional formative level assessment tool.

Table 4.15.

*Achievement scores of the students in the subject of chemistry (practical) collected through second traditional formative level assessment tool.*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>3.9</td>
<td>1.4</td>
<td>1.13(74)</td>
<td>&lt;.261</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>4.3</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The *t*-test was applied to discover whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the second term assessment tool. The result showed that the mean and S.D. values for the Johnstone’s instructional method (*M*=4.3, *SD*=1.7) were not significantly greater than the mean and S.D. values for the traditional instructional method (*M*=3.9, *SD*=1.4, and *t*(74)=1.13

The mean score of the experimental group (4.3) was greater but not significantly greater than the mean score of the control group (3.9). It showed that the difference in achievement was not a significant difference. Therefore the hypothesis formulated above was accepted. The second traditional level assessment tool stressed on the low cognitive demands. The traditional assessment stressing recall and memory aligned with the traditional instructional method. The students taught through traditional method just received the information and had to reproduce the same.
Traditional assessment was not concerned with the conceptual understanding and was not required to assess it. So it can be inferred that traditional way of assessment cannot properly measure the conceptual understanding. Therefore, learning with understanding, need to be tested by questions having high cognitive demands or higher cognitive levels. The students taught through constructivists methods perform well when they are tested correspondingly and voice versa. The findings of this study supported the findings of Shepard (1992), Osborne and Cosgrove (1983), Sawrey (1990), Andesson (1990), Bodner (1991),and Gabel (1999). The importance of aligning teaching methods and assessment tasks was greatly emphasized (Osborne, 2004). This means that assessment should not lay emphasis on recall and memorization. The learning should be regarded more in qualitative terms than the quantitative terms.

The performance of the control group was equally effective with that experimental group and it was an alignment of teaching method and assessment task as conceptualized by Osborne (2004). Teaching and assessment are important part of learning process but interact with each other (Danili & Reid, 2006). Table 4.15 shows the comparison of achievements of experiment and control groups. Figure 4.15 further clarifies the data analysis. The statistical analysis of the subsequent hypothesis is given on page 177.
Figure 4.15. Comparative achievement scores of the students in the subject of chemistry (Practical) collected through second traditional formative level assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at second traditional formative level assessment tool.

Table 4.16

Achievement scores of the students in the subject of chemistry (Theory + Practical) collected through second traditional formative level assessment tool.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>27.9</td>
<td>12.0</td>
<td>0.34(74)</td>
<td>&lt;.735</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>29.0</td>
<td>14.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $t$-test was applied to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method as measured by the second traditional formative assessment tool. The result showed that the mean and S.D. values for the johnstone’s instructional method ($M=29.0$, $SD=14.8$) were not significantly greater than the mean and S.D. values for traditional instructional method ($M=27.9$, $SD=12.0$), and $t=0.34(74)$. The mean score of the experimental group (29.0) was greater than the control group but was not significantly different than mean score of the control group (27.9). It showed that the difference in the achievement was not significant. Therefore the hypothesis formulated above was accepted. The performance of the experimental and control group was equal. The alignment was found between the teaching method and assessment task in case of control group. The alignment did not exist between teaching method and assessment task in case of experimental group. The low
performance of the experimental group was due to the mismatch of the teaching method and assessment task. The test constructed was of conventional nature and it was meant for measuring recall. The conventional assessment tasks were not meant for measuring meaningful learning. The findings of this study support the findings of Bunce, Diane M et al. (2006), Danili and Reid (2006). The findings of this study are consistent with the findings of Barren (1971), Moore (1973), and Goodman (1977). Table 4.16 shows a comparison between the two instructional methods on traditional formative assessment mode. Figure 4.16 also helps to understand the relationship between traditional instructional method and traditional assessment. The statistical analysis and explanation of the next hypothesis has been given on page 180.
Figure 4.16. Comparative achievement scores of the students in the subject of chemistry (Theory + Practical) collected through second traditional formative level assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method at post-test level assessment tool.

Table 4.17.

*Achievement scores of the students in the subject of chemistry (Theory) collected through post-test*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>32.8</td>
<td>7.5</td>
<td>4.9(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>43.5</td>
<td>10.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The *t*-test was applied to find whether there was any significant difference between the achievement scores of pupils in the subject of chemistry (Theory) taught through Johnstone’s instructional method and the traditional instructional method as measured by the post-test assessment tool. The result showed that the mean and S.D. values for Johnstone’s instructional method (*M*=43.5, *SD*=10.8) were significantly different than the traditional instructional method (*M*=32.8, *SD*=7.5), and *t* (74) =4.9.

The data in the table 4.17 shows that the mean score of the experimental group (43.5) was better than the control group (32.8). Therefore; the above stated hypothesis was rejected. The view of figure 4.17 revealed that the students who were taught through Johnstone’ instructional method performed better than the students who were taught through traditional instructional method. The results of this study were in agreement with the Fensham (1994), Shwartz et al. (1997), Nussbaum (1997), Tsaparlis, (2000). It can be inferred that Johnstone’s instructional method fits well with constructivist teaching and learning methodology and is quite suitable for
meaningful learning and conceptual understanding. Table 4.17 reveals the positive effect of Johnstone’s instructional method on learning of chemistry concepts with understanding. For the purpose of further clarity the mean scores have been given pictorially in Figure 4.17. Statistical analysis and explanation of the next hypothesis has been given on page 183.
Figure 4.17. Comparative achievement scores of the students in the subject of chemistry (Theory) collected through post-test assessment tool.
Ho18. There is no significant difference between the achievement scores of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method at post-test level assessment tool.

Table 4.18

*Achievement scores of the students in the subject of chemistry (Practical) collected through post-test*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>5.8</td>
<td>1.1</td>
<td>10.1(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>8.2</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The *t*-test, as a test of significance, was applied to find whether there was any significant difference between the performance of the students in the subject of chemistry (Practical) taught through Johnstone’s instructional method and the traditional instructional method as measured by the post-test assessment tool. The significant mean difference was observed between the pupils taught through Johnstone’s instructional method and the pupils taught through traditional instructional method. The result showed that the mean and S.D. values for Johnstone’s instructional method (*M* = 8.2, *SD* = 0.9), were significantly different from the values on traditional instructional method (*M* = 5.8, *SD* = 1.1) with *t* = 10.1(74) = 10.1.

The mean score of the experimental group (8.2) was higher than the control group (5.8). Therefore, above stated hypothesis was rejected.

The findings of the present study verified the findings of Valanides (2000), Rappoport (2008), Baviskar, et al. (2009). Table 4.18 clearly shows the positive effect of Johnstone’s instructional method on meaningful learning in chemistry and reveals
that Johnstone’s instructional method carries value for learning and instruction of chemistry. In order to increase the clarity and elaboration, the data have been presented in figure 4.18. The statistical analysis and explanation of the next hypothesis is given on page 186.
Figure 4.18. Comparative achievement scores of the students in the subject of chemistry (Practical) collected through post-test assessment tool.
There is no significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and the traditional instructional method at post-test assessment tool.

Table 4.19.

Achievement scores of the students in the subject of chemistry (theory + practical) collected through post-test

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>38</td>
<td>38.6</td>
<td>8.5</td>
<td>5.5(74)</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Experimental</td>
<td>38</td>
<td>51.7</td>
<td>11.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $t$-test was applied to find whether there was any significant difference between the achievement scores of the students in the subject of chemistry (Theory + Practical) taught through Johnstone’s instructional method and traditional instructional method as measured by the post-test assessment tool. The results showed that the mean and S.D. values for Johnstone’s instructional method ($M$=51.7, $SD$=11.7), and $t$=5.5(74) were significantly different than the traditional instructional method ($M$=38.6, and $SD$=8.5).

The mean score of the experimental group (51.7) was significantly different than the control group (38.6). Therefore, the null hypothesis formulated above was rejected. The observations made by this study verified the observations made by Cokelez and Dumon (2005), Toomey et al. (2001).

Table 4.19 make it clear that the pupils taught through Johnstone’s instructional method performed better than the pupils taught through traditional instructional method. It means that the students absorbed the concepts more...
effectively. Johnstone’s instructional method is quite suitable for the conceptual understanding of the chemical concepts. Chemistry needs to be taught at three levels. Chemistry mostly deals with concepts that are abstract in nature and are a source of difficulty for the secondary science students. Hierarchical introduction of chemistry concepts facilitates the learning and assimilation of concepts. The important thing revealed from the data was that alignment existed between teaching method and assessment tasks. As learning is a process of meaning making and similar assessment task needs to be utilized to measure this meaning making ability. The main purpose of assessment should be to minimize the emphasis on the rote learning and stressing learning with understanding. When the teaching method and assessment task match, well, the student’s ability to produce cogent and an adequate answer is quite enhanced. Figure 4.19 further clarifies the effects of Johnstone’s instructional method on learning and instruction.
Figure 4.19. Comparative achievement scores of the students in the subject of chemistry (Theory + Practical) collected through post-test assessment tool.
CHAPTER 5

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter deals with the summary, findings and conclusions of the study. The recommendations have also been drawn from the findings and conclusions of this study and the discussion has been divided into the following headings.

5.1 Summary

In Pakistan, science instruction at secondary level heavily draws on traditional instructional model called lecture method. Traditional method believes in the passivity of the learner and just has to receive the content actively delivered by the teacher. Here the teacher is seen as sole and infallible source of information. The lecture method draws on the assumption that the students are devoid of related prior knowledge. The students are just required to memorize the information. The students are not supposed to learn by engaging and by doing. The transmission mode of teaching ignores the premise that the learners are innately active and have ability to construct knowledge. When the innate abilities of the learners’ i.e. prior knowledge and capacity to construct knowledge are ignored they heavily depend on memorization and faulty conceptual development. In this situation the students in spite of having familiarity continuously fill their heads with the unrelated, irrelevant and disconnected material. Hence, teacher goes on without taking into account the way students learn. When the students use this mode of learning they fail to achieve the higher cognitive skills. The students learn actively when they are in their concrete operational stage and learn by doing. Therefore familiar, interesting and attention catching components must compose and constitute the teaching learning situations.
In most of the Pakistani schools chemistry is being treated traditionally. The teachers follow linear development of concepts without concerning for the way students learn concepts and learning these with understanding. Similar is the situation with the practical work. The practical work is being used to verify the already established knowledge. This is not the real essence of education. The teaching and learning need to be started from a different perspective.

Traditional approaches to teaching are in practice specifically in the teaching of science in Pakistan along with their strengths and weaknesses. The findings of this work strongly suggest shifting of the paradigm from transmission approach to constructivist approach. The present study is an attempt to contribute to periodical improvements by making use of the ideas put forward by Johnstone to promote student understanding especially in chemistry.

Due to the inadequate and insufficient it was decided to delimit the work to:

- 76 male science students
- Ninth grade chemistry
- Federal Government Boys Model F-8/3 Islamabad (Pakistan).

In this study the following measurement procedures were used. These tests were administered to the sample.

1. Posttest achievement test (chemistry theory and practical).
2. First and second traditional formative assessments in the theory and practical.
3. Macro level achievement test (theory and practical)
4. Symbolic level achievement test (theory and practical)
5. Sub micro level achievement test (theory and practical)

Ninth class science students of Federal Government Boys Model F-8/3 Islamabad were divided into two equivalent groups on the basis of achievement
scores in the subject of eighth grade science. One group was randomized and selected and regarded as experimental group and the other was called as control group. The experimental group was treated by the Johnstone’s instructional method whereas the control group was treated by the traditional instructional method. The intervention continued for 22 weeks. Daily study period comprised of 40 minutes.

Two periods per week were devoted for the practical work. The experimental group was extra treated before the practical work in the zero periods and named as chemistry prelab. The chemistry prelab was delivered in the form of lecture. The work schedule was set, harmonized with and strictly followed the regular time table of the institution. The design that was considered most adequate and appropriate for the study was “posttest only equivalent group design”. Hypotheses of the study were tested by the $t$-test and the statistical significance between the means was also calculated by the $t$-test.

During the study three formative assessments (theory and practical) were made to get the feedback for further improvement. At the end of the study posttest (theory and practical) was administered to check the gains.

On the whole, the results of the data analysis strongly favored Johnstone’s instructional method. Most of the null hypotheses were rejected which proved that Johnstone’s instructional method is more effective than the traditional instructional method in the teaching of chemistry at secondary school level.

Based on the above outcomes, some factors seem to have the potential to affect the study. The factors or weaknesses are addressed as under:

A. Both the teachers in spite of having similar experience and qualification are different individuals. Personality difference and teaching perceptions may weaken the study. This factor was neutralized by informing the teachers about
the purpose of the study and pedagogical training about the traditional instructional method. There exists a chance of interaction between the new constructivist method and the researcher who might have been and lacked by the other teacher. This factor is not enough to make the study invalid but the weakness mentioned can be checked and removed by involving more randomized matched groups, more teachers and researcher. This multiple comparison will act as an important tool and will reveal very important results.

B. The small sample of boys only is a limitation but it does not invalidate the study. The sample size can be increased by adding girls in future studies.

C. It is human nature, the humans respond positively to the new and interesting things. As the method was entirely different than the traditional one, there exists a chance of peer interaction. The weakness can be removed by taking experimental and control group in separate institutions.

D. Assessment is a complex process. Certain important areas of assessment have been ignored. The constructivist teaching methods demand qualitative assessment and not quantitative assessment. Essay type questions are more suitable for measuring meaningful learning. The multiple questions can be easily constructed and tested but not suitable to measure learning with understanding. In future, studies should match the instructional method and the assessment tasks.

E. Assessment is an integral part of teaching and learning. Different formats need to be used to assess different types of performances and abilities. It does not work in vacuum but act dynamically with the teaching and learning. It is evident that the students mould themselves according to the questions asked. Assessment needs to be utilized as a tool to shift the paradigm from recall to
meaningful learning. The examination system only checks the recall and memorization. If the shift occurs from traditional instruction to constructivist instruction, there will also be shift in the learners. They will stress less to just pass the examination and learn more how to learn meaningfully and solve the problems of their daily life.

F. Thus a very interesting picture that emerges from that the assessment tasks were instruction oriented, performance, competency and ability oriented.

### 5.2 Findings

Findings of the study, drawn out from the analysis of data are given as under:

1. There was no significant difference between the achievement scores of the students of ninth class in the eighth class science achievement test before the start of experiment.

2. At macro level achievement test (theory), the mean score of the experimental group was 16.28 and that of control was 10.86. The difference between the means was statistically significant in favour of experimental group.

3. At macro level achievement test (practical) the mean score of the experimental group was 3.68 and control group was 1.71. The difference between the means observed was statistically significant in favour of experimental group.

4. Overall achievement of the experimental group at macro level achievement (theory + practical) was 19.97 and the mean of the control group was 12.52. The difference between the means was statistically significant in favour of experimental group.

5. At micro level achievement test (theory) the mean score of the experimental group was 17.15 and the mean of control group was 9.31. The difference
between the means was statistically significant in favour of experimental group.

6. At micro level achievement test (practical) the mean score of the experimental group was 3.94 and that of control group 1.78. The difference between the means was statistically significant in favour of experimental group.

7. The overall achievement of the experimental group at micro level achievement (theory + practical) was 21.10 and that of control group was 11.10. The difference between the means was statistically significant in favor of experimental group.

8. At symbolic level achievement test (theory) the mean score of the experimental group was 15.57 and that of control group was 7.71. The difference between the means was statistically significant in favour of experimental group.

9. At symbolic level achievement test (practical) the mean score of the experimental group was 3.47 and that of control group was 1.84. The difference between the means was statistically significant in favour of experimental group.

10. The overall achievement of the experimental group at symbolic level achievement (theory + practical) was 19.05 and that of control group was 9.55. The difference between the means was statistically significant in favour of experimental group.

11. At first traditional formative assessment achievement test (theory) the mean score of the experimental group was 22.71 and that of control group was 22.89. The difference between the means was not statistically significant.
12. At first traditional formative assessment achievement test (practical) the mean score of the experimental group was 4.39 and that of control group was 3.89. The difference between the means was not statistically significant.

13. The overall achievement of the experimental group at first traditional formative achievement (theory + practical) was 27.10 and that of control group was 26.78. The difference between the means was not statistically significant.

14. At second traditional formative achievement test (theory) the mean score of the experimental group was 24.65 and that of control group was 24. The difference between the means was not statistically significant.

15. At second traditional formative achievement test (practical) the mean score of the experimental group was 4.34 and that of control group was 3.94. The difference between the means was not statistically significant.

16. The overall achievement of the experimental group at second traditional formative achievement (theory + practical) was 29 and that of control group was 27.94. The difference between the means was not statistically significant.

17. On posttest (theory) the mean score of the experimental group was 43.55 and that of control group was 32.84. The difference between the means was statistically significant in favour of experimental group.

18. On posttest (practical) the mean score of the experimental group was 8.21 and that of control group was 5.84. The difference between the means was statistically significant in favour of experimental group.

19. The overall achievement (theory + practical) on posttest the mean score of the experimental group was 51.76 and that of control group was 38.68. The
difference between the means was statistically significant in favour of experimental group.

5.3 Conclusions

1. Johnstone’s instructional method (three tier representation) of chemistry was found more effective than traditional instructional method in improving the achievement of the students in the subject of chemistry as measured by the posttest achievement test.

2. The distinction of chemistry concepts at macro level and instruction significantly improved the ability of the students to understand the chemical concepts.

3. The macro level representation of chemistry concepts also improved the learning of the students in the chemistry laboratory.

4. The micro level distinction of chemistry concepts and instruction significantly improved the achievement of the students. The micro level when made visible and tangible it significantly helped in the concept formation.

5. Micro level practical work was used for the purpose to conceptualize the macro level chemical concepts. It was also used to establish link with macro representation.

6. The symbolic level or iconic level distinction of chemistry concepts and instruction also helped to raise the achievement level and learning with understanding.

7. The symbolic level instruction also helped the students to learn the chemistry concepts more effectively and efficiently. The students frequently interconverted and interconnected the macro and symbolic representations.
8. Jonhstone’s instructional method was found to promote and enhance the meaningful learning.

9. An interesting picture that emerged from the data analysis was that nature of assessment significantly affected the achievement of the experimental group. It was concluded that there was a mismatch between the meaningful learning and the style of assessment. Traditional assessment matched with the traditional instruction.

10. It was also concluded that the effectiveness of constructivist instructional methods which stresses meaningful learning can be effectively evaluated through qualitative measurement instead of measuring through quantitative assessment tasks. Hence, essay type and short answer type questions are more useful for this purpose.

### 5.4 Recommendations

1. In Pakistan science of teaching and the science of learning are still in the initial stages of development. Research and practice need to be integrated. Classroom instruction, learning and practical work need to be fully exposed and linked with modern brain science research so that the unanswered areas may get the answers.

2. In case we see the instructional and learning continuum, we lie at the traditional end but the present study recommends that we must be at the meaningful end.

3. The present study carries value for instruction and learning area and its effectiveness needs to be replicated on diverse sample region.
4. Keeping in view the findings of this study the instructional and learning material needs to be so designed as to make chemistry classroom and laboratory more effective and learning oriented.

5. Teachers depend on knowledge verification end of the practical work continuum. There is need to rethink the aims of the practical work, learning in and from science laboratory especially at secondary level is recommended. There is need to design on the knowledge construction end of the practical work continuum.

6. Chemistry, like other disciplines, works at three thought levels. The role and value of these levels is well documented and supports the findings of Tsaparlis and Georgiadou (2000), Tsaparlis (2000). It is recommended that this method be adopted in Pakistan.

7. As the innovative teaching methods stress meaningful learning, the traditional ways of assessment are not dependable especially at secondary school level. Hence the assessment system in Pakistan requires extensive overhaul.

8. Positive influence of the teaching method, particularly when used by the textbook, is larger. Therefore, the secondary chemistry textbook be developed as per levels of thought methodology. The curriculum developers also be asked to develop the curricula according to the levels of thought methodology.

9. Working teachers may also be trained in the light of the sequence proposed by the levels of thought methodology and the refresher courses be organized.

10. Levels of thought approach be adopted for the teaching of other science disciplines such as biology and physics. Further researcher studies need to be planned in other science disciplines in order to find out the effectiveness of this methodology.
References


Committee on Science Learning, Kindergarten through Eighth Grade *Taking Science to School: Learning and Teaching Science in Grades K-8*; Duschl, R.,


Taloomey, R. (2001). Helping students to make inferences about the atomic realm by delaying the presentation of atomic structure, *Chemistry Education Research and Practice, 2*, 129-144.


Appendix-A

Group Formation (Experimental & Control)

Marks obtained by the students in the subject of eighth class science (Max.Marks:100)

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Appendix-B

Experimental Group

Marks Achieved by the students in the subject of chemistry (part 1)
theory & practical during the session 2010-2011.

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Appendix-C

Control Group

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Appendix-D

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Mean Score: 24.65 4.31 29
Control Group

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Appendix –E

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Control Group

Marks achieved by the students in the subject of chemistry (Theory & Practical) in the post-Test.

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Appendix-F

First Traditional Formative Assessment Tool

Time: 2:30 Hours                      Marks: 50

Q.1 Write down the short answers of the following (any ten)

i) Define organic chemistry and Biochemistry?

ii) Who were Alchemists and what was their belief?

iii) Show the relationship of different disciplines of science with the help of a diagram?

iv) Define and explain law of definite proportions?

v) Define radicals & give examples?

vi) Define and explain molecular formula with the help of examples?

vii) What is atomic spectrum?

viii) Define isotopes and explain it with an example?

ix) Write down any three properties of alpha rays?

x) Define mole and molar mass/

xi) What is the contribution of Robert Boyle, Faraday and John Dalton in chemistry?

xii) What was the Greek concept of Elements?

Note: Attempt any two questions from the following

\[ 2 \times 10 = 20 \]

Q.2 Describe the types of chemical reactions?

Q.3 Write down the contribution of following Scientists in Chemistry?

Q.4 Describe discovery of Electron? Write down the properties of Cathode rays.
Appendix-G

Second Traditional Formative Assessment Tool

Time: 20 Minutes
Marks: 12

Section-A (Objective)

Q.1 Choose the correct answer

i) The branch of chemistry which deals with the melting and appearance of state of a substance is
   a) Physical chemistry  (b) Inorganic chemistry
   c) Organic chemistry  d) Bio chemistry

ii) The concept of four elements was given by
   a) Greek  b) Egypt  c) English  d) Arabs

iii) The composition of Aqual Regia is chemically of
   a) Two acids  b) Three Acids
   c) Four Acids  d) Two bases

iv) In water composition ratio of H and O by weight is
   a) 2:1  b) 1:2  c) 1:8  d) 8:1

v) In the law of multiple proportion there must be ______ elements.
   a) Tow  b) Three  c) Four  d) Five

vi) The number of neutrons in $^{24}_{\text{Cr}}$ is
   a) 24  b) 51  c) 27  d) 75

vii) Modern periodic table has been divided into _______ blocks
    a) 2  b) 3  c) 4  d) 5

viii) Location of transition metals in periodic table is
     a) Left  b) Right  c) Middle  d) Bottom

ix) The element with the highest electro negativity is
    a) F  b) Cl  c) O  d) H

x) Hydrogen bonding is represented by
    a) $\cdots\cdots\cdots$  b) (X)  c) (…..)  d) (_____

xi) The escape of air from a balloon is called
    a) Diffusion  b) Evaporation
    c) Condensation  d) Boiling

xii) Fog is a type of solution
     a) gas to gas  b) gas in liquid
     c) liquid  d) liquid in liquid

…………………………………..
Second Traditional Formative Assessment Tool
Time: 2:30 Hrs.   (Subjective Type)   Marks: 80
Section-A (33 marks)

Q.2 Attempt any eleven parts. The answer to each part should not exceed 3 to 4 lines.

i) Indicate three disadvantages of chemistry.

ii) How many atoms are present in the following?
    CaCl$_2$   Cu (OH)$_2$   H$_2$SO$_4$

iii) Write chemical formula of the following
    Oxalic acid   Sodium Thiosulphate   Sodium chloride

iv) What is meant by Artificial Radioactivity?

v) Define isotope and draw isotopes of Hydrogen.

vi) Which elements are responsible for the different colours of hair of different people?

vii) Why there are vacant spaces in Mendeleev’s periodic table.

viii) Consider the following elements
     Neon   Iodine   Mg
     Which element sublimes?
     Which elements used in tube light.
     Which element is alkali earth metal

ix) What type of Bond is formed between NH$_3$ and BF$_4$. Explain

x) Why it is easy to compress air as compare to water.

xi) What is Octet rule?

xii) What is freezing mixture give example?

xiii) Define saturated solution super saturated solution.

xiv) What is phlogiston theory who developed this theory?

xv) Define empirical formula and draw structure of sand.
Section-C (20 marks)

Note: Attempt any two questions.

Q.3 Define solubility and factors affecting solubility.

Q.4 Write four types of chemical reactions also give examples.

Q.5 Write Bohr’s Atomic model in detail.
Appendix H

Sub-Micro Level Formative Assessment Tool for Class IX Chemistry

(Theory)

Maximum Marks: 20                                      Name:_________________________

Time: 1Hr                                               Roll No. _______________________

Note: Read the statements carefully and answer the following questions.

Q.1. What happens to an element when it passes through the radioactivity?

Q.2. Why alpha rays bend towards negative pole while passing through an electric
     or magnetic field.

Q.3. What happens to the total energy of the system when atoms come close to each
     other to form molecule.

Q.4. How hydronium ion is formed.

Q.5. How the melting and boiling points of polar compounds are increased.

Q.6. Why acetic acid is a weak electrolyte.

Q.7. Why spectator ions are called so.

Q.8. Give the diagrammatic representation of oxygen atom.

Q.9. How basic salts are formed. Give at least two examples.

Q.10. Differentiate Lewis acid from Lewis base with the help of an example.
Sub-Micro Level Formative Assessment Test (Practical)

Time allowed: 1: Hour

Total Marks: 05

1. Prepare crystals of potash alum. 03 marks

-OR-

2. Determine the pH of provided solutions by pH paper.

Record keeping 01: mark

Viva Voce 01: mark
Macro Level Formative Assessment Tool for Class IX Chemistry

(Theory)

Maximum Marks: 20

Name: ______________________

Time: 1Hr

Roll No. ______________________

Note: Read the statements carefully and answer the following questions.

Q.1. When a mixture of iron and copper oxide is heated, a pink colored substance is seen. This is due to the reaction, give the relevant reaction.

Q.2. How dissolution of solute in a solvent occurs.

Q.3. Table salt dissolves in water but not petrol.

Q.4. It has been seen that when electricity is passed through aqueous solution of sodium chloride, the bulb glows whereas the bulb does not glow when electricity is passed through the aqueous solution of sugar why?

Q.5. What is the effect of higher concentration of metal in its electrolyte in electroplating?

Q.6. How salt is formed

Q.7. How potash alum is formed.

Q.8. What does pH of a solution indicate?

Q.9. What is the role of polarity in solution formation and solubility?

Q.10. Why a liquid does not have a fixed shape.
Macro Level Formative Assessment Test for Class IX Chemistry

(Practical)

Time allowed: 1: Hour Total Marks: 05

1. Prepare saturated solution of copper sulfate 03 marks

-OR-

2. Determine the boiling point of ethyl alcohol

Record keeping 01: mark

Viva Voce 01: mark
Posttest Assessment Tool for Class IX Chemistry (Theory)

Maximum Marks: 12

Name: ____________________________

Roll No. ____________________________

Time: 20 Minutes

Section---A (objective)

Note: Read the statements carefully and choose the most suitable answer.

Q.1 Choose the correct answer.

i. The mass ratio of hydrogen and oxygen in water is
   (a) 1:8   (b) 8:1   (c) 1:2   (d) 1:4

ii. The number of lone pairs of electrons in ammonia are
    (a) 1   (b) 2   (c) 3   (d) 4

iii. The number of electrons in the valence shell of deuterium are
     (a) 1   (b) 2   (c) 3   (d) no electron

iv. The similar elements in the sets of three were arranged by
    (a) Mendelev  (b) Doberiener  (c) Newland  (d) Lothar Meyer

v. The coordinate covalent bond is symbolized by
   (a) ─  (b) ＝  (c) ≡  (d) →

vi. The number of electron pairs in nitrogen molecule are
    (a) 2   (b) 3   (c) 1   (d) none

vii. Water has maximum volume at
     (a) 0 C⁰  (b) 1 C⁰  (c) 3 C⁰  (d) 4 C⁰
viii. The liquids having free movement of molecules are called

(a) Conductors                    (b) non-conductors

(c) non-electrolytes & non-conductors (d) electrolytes

ix. Water is a

(a) Weak electrolyte             (b) strong electrolyte

(b) Non-electrolyte              (d) conductor

x. A chemical reaction in which electrons are lost is called

(a) Reduction       (b) oxidation (c) oxidation-reduction (d) electrolysis

xi. The number of replaceable hydrogen atoms in phosphoric acid are

(a) 2     (b) 1    (c) 3     (d) 4

xii. The number of water molecules in epsom salt are

(a) 3     (b) 5    (c) 6     (d) 7
Posttest Assessment Tool for Class IX Chemistry

(Theory)

Maximum Marks: 33

Name: ______________________

Time: 2:30 Hrs

Roll No. ________________

Section—B (Subjective Type)

Q.2 Attempt any eleven parts. The answer to each item should not exceed 3 to 4 lines.

i. How chemistry is facilitating mankind.

ii. Find out the molecular mass of the following compounds.

NaOH, Na₂CO₃, and H₂SO₄

iii. Balance the following equations

Na + H₂O → NaOH + H₂

KBr + Cl₂ → KCl + Br₂

Al + Fe₂O₃ → Fe + Al₂O₃

iv. What happens when a gas is introduced in a discharge tube at a low pressure

v. Give the electronic configuration of Magnesium, sodium and oxygen.

vi. Can valence shell predict the behavior of the element.

vii. Why metals have low ionization energy.

viii. What is the effect of heating on liquid.

ix. How dipole-dipole forces originate

x. How polarity is important for solubility

xi. What happens to electrolytes when put in water or heated.

xii. How lead storage battery is recharged
xiii Why acetic acid is a weak acid in spite of having four hydrogen atoms.
xiv How hydronium ion is formed
xv How the process of neutralization occurs.
xvi How an adduct is formed
xvii 40 gram of sodium chloride solution contains 5g of sodium chloride. determine its percentage by mass.

Section---C (20 marks)

Note: Attempt any two questions.

Q.3. Compare the theories of acid and base with examples.

Q.4. How coordinate covalent bond is formed? How this bond is different from covalent bond.

Q.5. Explain why?
   i. Metals are good conductor of electricity.
   ii. High pressure changes the shape of metals.
   iii. The melting and boiling points of metals are usually very high.
Posttest Assessment test for Class ix Chemistry (practical)

Time allowed: 2 Hours  Total Marks: 10

1. Prepare the crystals of copper sulfate. (Minor experiment) 02

2. Identify the given substances as electrolytes or non-electrolytes by passing electric current. 04

-OR-

Standardize the given solution of hydrochloric acid using sodium hydroxide (0.1M).

Recording of results 02

Viva Voce 02
Appendix I

SYMBOLIC LEVEL FORMATIVE ASSESSMENT TEST (THEORY)

CLASS IX CHEMISTRY

Time: 1 Hr
Marks: 20

Q.1 Write the names of the following chemical compounds.

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<td>CH₃COOH</td>
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<td>NaCl</td>
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<td>Al₂O₃</td>
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<td>NH₄Cl</td>
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Q.2 Write the chemical formulae of the following compounds

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<td>Magnesium Sulphate</td>
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<td>Barium Sulphate</td>
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Q.3 Write the following chemical equations in words:

Example: H₂ + Cl₂ → 2 HCl

Hydrogen and chlorine react to form hydrogen chloride.

1. Zn + H₂SO₄ → ZnSO₄ + H₂
2. \( \text{Mg} + \text{O}_2 \rightarrow 2\text{MgO} \)

3. \( \text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2 \)

4. \( \text{NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} \)

5. \( \text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3 \)

Q.4 Write the following chemical equations by using chemical formulae:

Example: Hydrogen and oxygen react to form water.

\[ \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \]


2. Hydrogen and Iodine react to form hydrogen iodide.

3. Sodium hydroxide and hydrochloric acid react to form salt and water.

4. Ammonium hydroxide and sulfuric acid react to form ammonium sulfate and water.

5. Potassium chlorate on heating decomposes to potassium chloride and oxygen.
SYMBOIC LEVEL FORMATIVE ASSESSMENT TEST
(PRACTICAL)

Time allowed: 1 Hour  Total Marks: 05

1. Prepare 0.05 M standard oxalic acid solution (1Litre).  03 marks

-OR-

2. Standardize the given solution of sodium hydroxide using oxalic acid solution (0.05 M).

Record keeping  01: mark

Viva Voce  01: mark
Appendix J

1. Determination of melting points of the given compounds having melting point less than 1000°C.

2. Determination of boiling points of the given liquid boiling at less than 1000°C.

3. Preparation of saturated solution of copper sulphate.

4. Crystallization of copper sulphate.

5. Preparation of potash alum.

6. Determination of pH of different solutions with the help of pH paper.

7. Preparation of standard oxalic acid solution.

8. Standardize the given solution of sodium hydroxide using oxalic acid solution.

9. Standardize the given solution of hydrochloric acid using oxalic acid solution.

10. Passage of electric current through electrolytes non electrolytes and to record the observations and classify them (National curriculum 2000).