Contents

Chapter 1

Introduction

1.1 Background of the study

There have been reports on how learning styles and instruction affects students' academic performance/achievement (Bell, 2007; Hargrove, Wheatland, Ding, & Brown, 2008; Ross, Drysdale, & Schulz, 2001; Yeung, Read, Robert, & Schmid, 2006). But, these reports were more general to apply specifically to chemistry education. These reports did not consider how the nature of chemistry together with learning styles affect the nature of chemistry instruction and consequently affect students' academic performance. Moreover, there is no literature that documented learning style model specific for chemistry education.

On the other hand, literatures on learning styles show that different learning style models that suggest the application of differentiated instruction were developed based on the assumptions of learners' diversity (Cassidy, 2004; Dunn, Griggs, Olson, Beasley, & Gorman, 1995; Dunn, et al., 2009; Felder, 1989; Honigsfeld & Schiering, 2004). However, there seems to be no literature on how to integrate learning styles into chemistry education metaphors.

Literatures on chemistry education show that the metaphors of chemistry education which influenced chemistry education were developed based on the assumptions of the nature of chemistry (Johnstone, 2004; Mahaffy, 2004, 2006). These literatures fail to consider how learner related variables including learning styles influence chemistry education.

Therefore, the current study, as part of a scientific effort designed to integrate learning styles in to chemistry education metaphors, has the following purposes. The first purpose is: a) to determine the amount of variation in students' academic performance on some fundamental concepts in the topics: Atomic structure and periodic table, Chemical bonding and structure, Acid-base equilibrium and common Thermodynamic terms which could be explained by learning styles, and b) to identify learning styles that best enhances students' academic performance in chemistry. The second purpose is to explore the role of instructional materials on academic performance in chemistry among science students with different and the same learning styles. The third purpose is to integrate a specific learning styles model into the literatures of chemistry education and suggest how to apply it in the teaching-learning process of chemistry. As a consequence, the findings of this study could explain and describe students' academic performance in chemistry in terms of learning styles and instructional materials. This could in turn provide useful information for science students, and chemistry curriculum and/or instructional designers in their teaching-learning process. It might also give ideas on how to integrate learning styles and promote individual learning in science education program.

According to Cassidy (2004) "there is general acceptance that the manner in which individuals choose to or are inclined to approach a learning situation has an impact on performance and achievement" p.420. This tends to imply that every student has an individual preference to learning situations that can affect his/her achievement and performance. One of students' differences in terms of preferred approach to learning situation (such as text book, classroom environment etc) can be learning styles. In connection to this, Sims and Sims (1995) stated that "instructional design must be aimed at aiding the learning of the individual, not a group or class of individuals" pp.12. Based on the notion of learning styles that states individuals learn in different ways Honigsfeld and Schiering (2004) explain that learning style is a learner-centered approach and practice. Therefore, a learner-centered instructional strategies could reach to different learners and promote individual learning.

Scholars in the field of learning styles such as Dubetz, et al. (2008), Honigsfeld and Schiering (2004), and Timothy and Kimberly (2010) argue that multiple instructional strategies are important to reach individual students with different learning styles. Hence, applying a number of instructional strategies to teach a single topic could be helpful to aid academic success of learners with different learning styles.

However, the use of different instructional strategies to teach a single topic may incur extra time, effort, and resource. For example, if one considers Felder-Silverman's learning style model, it has four bipolar learning style dimensions, such as Visual/Verbal, Sensing/Intuitive, Active/Reflective, and Sequential/Global dimensions. Each dimension of the learning styles is independent of each other and hence there are a total of eight different possible learning styles. This may require us to present a single chemical concept (for instance, chemical bonding) in eight different forms or to use different instructional strategies suits to the independent learning styles. Chemical concepts should be presented to support Visual, Verbal, Sensing, Intuitive, Active, Reflective, Sequential and Global learners. Nevertheless, the unique nature of a particular chemical concept may not allow us to present it in eight different ways or using different instructional strategies.

Magnusson, Krajcik, and Borko (1999) argue that subject-specific research and unique disciplinary instruction is important for effective teaching. They continue to state that "topic specific representations" or "teachers" knowledge of ways to represent specific concepts or principles in order to facilitate students learning as well as, knowledge of the relative strengths and weaknesses of particular representations" can help "students in developing understanding of specific concepts or relationships" p. 111. Moreover, presenting a chemical concept in eight different ways could become resource intensive, and each form of presentations may not be equally understandable to students.

For example, the molecular structure of cholesterol can be well understood through its visual form of molecular presentation (Figure 1.1) than through verbal presentations. Verbal presentations might be difficult to provide accurate information about bond angle, spatial distribution of atoms and the density of charges of cholesterol molecule through oral or textual forms of presentations. In turn incomplete or inaccurate presentation of its molecular structure may lead students to develop misconception about the molecular structure of cholesterol.

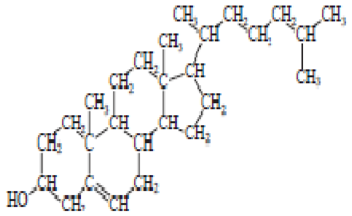


Figure 1.1 Representation of cholesterol (Eubanks, Middlecamp, Heltzel, & Keller, 2006, p. xii)

If instructional strategies selected based on learning styles, for example are applied in teaching different subjects or disciplines, it might not be effective in helping students as their learning styles sometimes fail to match the representational nature of that particular discipline's theory or concept. Consequently, the mismatch between the representational nature of chemical concept and preferred types of learning styles may marginalize some students and may also impair the quality of chemistry education. Therefore, identifying learning styles, which go along with the nature of chemistry, is worthwhile. This is the subject of the current study.

On the other hand, according to Towns (2001) the mismatch between learning styles preferences and the commonly used teaching methods and instructional strategies such as lecture, demonstration, instructor led problem solving, guided laboratory, and simulations in Science, Mathematics, Engineering and Technology (SMET) are some possible sources of students' frustration and switching from SMET majors to non-majors. Towns (2001) further explains that the fourth ranked reason of switching students from SMET major to non-major is connected with the decisions and use of teaching and instructional resources.

In a same study, Towns (2001) suggests that if chemistry community is to address issues of attraction and retention, emphasize is needed for diverse methods of delivering instruction and understanding learning style. Likewise, Dubetz, et al. (2008) mentioned that the use of multiple pedagogical approaches in chemistry education to address different learning styles may reduce attrition rate and improve performance. Therefore, accommodative instructions (learner-centered approach) may attract, retain (reduce drop out) and help in keeping quality of SMET education.

When looking into the African context of science education, Engida (2002) reported that the quality of science education in Africa, particularly in Ethiopia, is being criticized for its lack of relevance, criticality, and emphasis on "transmission model" of pedagogy. Such traditional method of teaching is not accommodative and may force students to switch out from SMET majors to non-majors (Towns, 2001). In this regard, my informal observations and discussions with students and science teachers, and my experience as a high school chemistry teacher (from between 2001 and 2002) and as a chemistry and pedagogy teacher at university (since 2002) is consistent with Engida's report.

My post graduate education and readings on: learning styles, philosophy of chemistry and history of chemistry had encouraged me to study and suggest plausible explanations to problems in Ethiopian high school chemistry education in terms of learning styles. Of course, quality problem of chemistry education might or might not be due to the match or mismatch between learner's preferred type of learning styles and the nature of chemistry instructional materials used in schools. However, from my readings and master's education on learning styles I suppose that the transmission model of pedagogy implemented in teaching chemistry in Ethiopia might result in the problem of mismatch between the nature of chemistry and learning style. Therefore, this further motivated me to conduct this study.

1.2 Trends on the influence of learning styles on science or chemistry education

Recent research in education indicate that one of the key challenges to keeping quality in science education is students' diversity such as learning styles, personality, culture, etc. To mention some, learning style is one of the important topical instructional variables that influences the choice of pedagogy such as instructional material development, classroom interactions and students' success in science (Moseley, et al., 2005; Pritchard, 2009). It might be for this reason that academics have given due attention to educational importance of learning styles (Lujan & Stephen, 2006; Margaret & Roberta, 2007; Timothy & Kimberly, 2010; Watson, 2007).

Moreover, at this age of "differentiated instruction" and the increasingly "heterogeneous classrooms" a tendency to look at learning styles as an instructionally relevant variable is important ("Learning style. Encyclopedia of Educational Psychology," 2008 ; Timothy & Kimberly, 2010). In this regard, scholars such as Ballone (2001), Chen (2001), Feldman (2003), Kolb (1981), and Kratzig and Arbuthnott (2006) argue that different learners have different learning style profiles and therefore they get benefitted from differentiated instruction.

Researchers in education attempt to apply research in learning styles framed under aptitude-treatment interactions (ATIs) to present explanations for academic achievement and school performance (Frisby, 2005). ATI theory suggests that optimal learning results when instruction is exactly matched to aptitudes, styles or preferences of the learner (Frisby, 2005). Frisby further describes that some instructional strategies (treatments) are more or less effective for particular individuals, depending upon their specific abilities, cognitive-learning styles, or learning preference.

Generally, there is a growing interest and number of researches on how learning styles influence education (Crutsinger, Knight, & Kinley, 2005; Gupta-Bhowon, et al., 2009; Kvan & Yunyan, 2005; Timothy & Kimberly, 2010; Yeung, Read, & Schmid, 2005), and on how the natures of science such as the nature of chemistry influence chemistry education (Jensen, 1998; Mahaffy, 2004; Scerri, 2001). In short, there are researches on one hand which mainly focus on the nature of chemistry and how it influences chemistry education (I can call it subject matter advocacy) sees Figure 1.2 below; and on the other hand on learning styles and how it shapes education (I can call it learning style advocacy) see Figure 1.3. However, still there is scarcity of literatures that explains the integrated effect of learning styles and nature of chemistry on chemistry education.

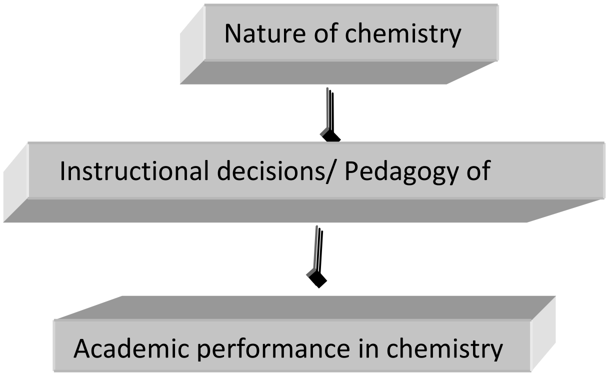


Figure 1.2 Instructional decisions based on Nature of chemistry (by subject matter

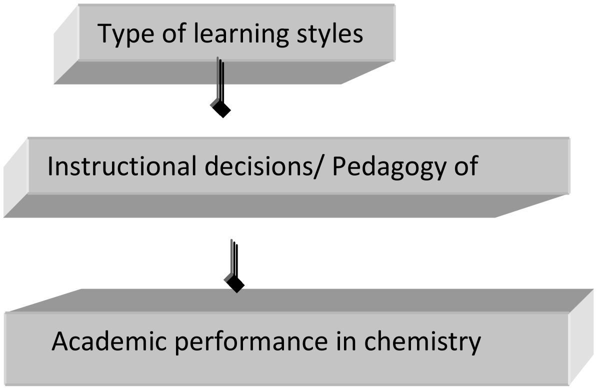


Figure 1.3 Instructional decisions based on the type of learning styles (by learning style

Researches designed to examine the impact of learning styles and the nature of chemistry on academic performance through instructional strategies are important in integrating learning styles in the pedagogy of chemistry. Neverthless, a few studies have made an attempt to integrate and show how the nature of chemistry and learning styles shape chemistry education (Al-Jaroudi, 2009; Gupta-Bhowon, et al., 2009; Yeung, et al., 2006) (see Figure 1.4).

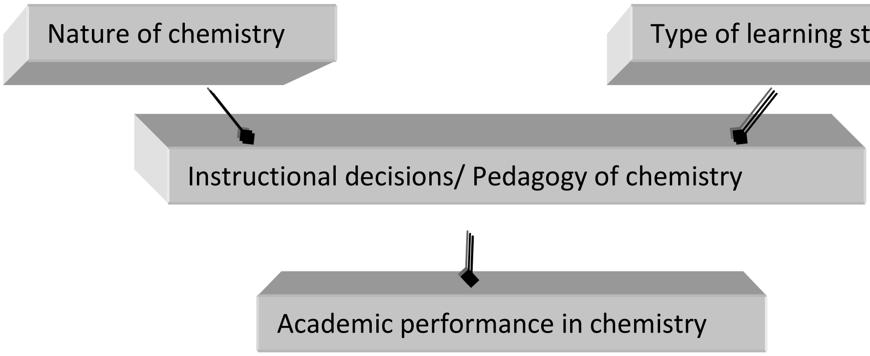


Figure 1.4 Instructional decisions/ Pedagogy of chemistry based on both natures of chemistry and learning

Moreover, Mahaffy (2004) has developed a tetrahedral metaphor of chemical education (see Figure 1.5) which attempted to integrate the nature of chemistry with the human element by extending the Johnstone's triangular planar models of chemistry education (Johnstone, 2006).

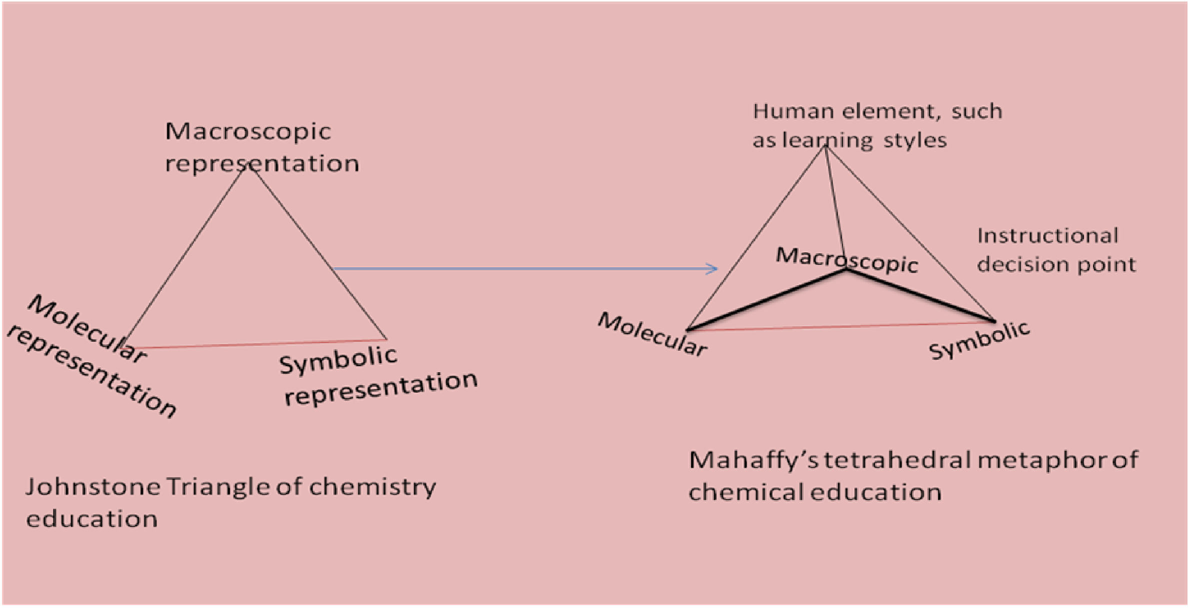


Figure 1.5 The tetrahedral of metaphor chemistry education adapted from (Mahaffy, 2004, p. 231).

Correlational studies conducted outside of Ethiopia showed that there is a correlation between learning styles and performance in SMET (Harold Broberg, Griggs, & Lin, 2006; Harvey, Ling, & Shehab, 2010). Likewise, Goodwin & Smith (2003) conducted a correlational research on visual, auditory, and tactile-kinesthetic aspects of learning styles and reported that tactile-kinesthetic learners perform better in general chemistry than others. But, this report does not go along with the general idea that there is no one best learning styles and one best teaching method.

Hence, this report remains valid until we prove that there are chemistry specific learning styles so that students with tactile-kinesthetic learning styles are expected to be successful in chemistry.

On the contrary, there are a study which shows that there is no statistically significant relationship between learning styles and performance in chemistry. For instance, Al-Jaroudi (2009) conducted a study on pre-service elementary teachers to examine the relation between Felder-Silverman learning style and students' conceptual understanding of chemistry and the particulate nature of matter in science classes. The study reported that, there was not statistically significant achievement gains or prediction related to differences in learning styles at α=.5 (Al-Jaroudi, 2009).

In sum, there is a scarcity of comprehensive study that investigated and showed which learning style and under what instructional context lead high school students to success in chemistry. The existing works were not enough to specifically show how learning styles (as a human element) together with the nature of chemistry influences instructional decisions and success in chemistry. Even these few existing literatures provide inconclusive evidence on which learning style model and how that learning style model, and nature of chemistry in a combined manner influence chemistry instruction and instructional material, and students' academic success. As a result the separate efforts made on how learning style and nature of chemistry affect chemistry education could put chemistry teachers and educators in dilemma or leave challenges to them in their choice of appropriate pedagogy of chemistry and chemistry instructional materials. Therefore, the current study may shed light on which learning style model and how that learning style model, nature of chemistry and instructional material are related to and explain academic performance in some fundamental concepts in chemistry.

1.3 Theoretical context of the study

The influences of learner's diversity on differentiated instruction

Students are diverse in different dimensions, such as learning styles (characteristic ways of taking in and processing information), approaches to learning (surface, deep, and strategic), and intellectual development levels (attitudes about the nature of knowledge and how it should be acquired and evaluated) (Felder & Brent, 2005; Feldman, 2003), and intelligences (individuals abilities and potentials that lead to academic successes) (Hoerr, 2000). These learners' diversities in the classroom have received attention of scholars in the field of education and are becoming a very interesting instructional variable to enhance learning and the quality of science education. Educators in different fields are becoming increasingly aware of the critical importance of understanding how individuals learn different subjects, and any attempts to integrate learning styles into education programs are made from an informed position (Cassidy, 2004, p. 420).

The influences of nature of chemistry on instruction

Different science disciplines (i.e. chemistry, biology, physics, etc) have different history, philosophy and nature of complexity (Allhoff, 2010; Gabbay, Thagard, & Woods, 2007). This disciplinary difference can also influence instructional design (McNeil, 1996), because the nature and logical structure of each discipline is unique and it leads to a particular way of representation and modeling (Ballone, 2001; Cullingford, 2004). By the same token, the unique nature and logical structure of chemistry may lead to a particular way of representation and modeling in chemistry education. Therefore, instructional materials should be discipline specific.

According to McNeil (1996), instructional materials should be designed based on the nature and logical structure of the subject matter. If instruction designed based on the nature of the subject matter match with leaning style (Stuart & Susan, 2009) and if student's mental structure exactly matches with the structure of the discipline (Soltis, 1991), learning and academic performance may be enhanced in that particular discipline. However, if there is a mismatch between the discipline specific instruction and learning styles , student's mental structure (learning) could be with defect or wrong connection compared with the discipline's structure, which is considered to be a misconception (McNeil, 1996). Hence, it should be noted that if instructional material is designed only based on a specific representational, model and modeling nature of the discipline, some disciplines may be friendlier to some learning styles but difficult to others.

On top of the idea that chemistry instructional materials should be specific to the nature of chemistry, chemistry instructional materials should also be match with learning styles. If chemistry education and/or instructional decisions are solely based on the nature of chemistry regardless of learning styles (i.e. if it mismatches with learning styles) it may put some students at risk. Of course, there are views that learning styles are discipline specific (Jones, Reichard, & Mokhtari, 2003). Thus, it is plausible to argue that student's academic performance on chemistry can be improved if there is a match between learning styles and pedagogy of chemistry, but still there is no conclusive evidence that show which learning styles suit to which discipline.

1.4 Statement of Purpose and Research Question

1.4.1 The Purpose

The study has three purposes.

1) The first purpose is: a) to determine the amount of variation in students' academic performance in some fundamental concepts in the topics: Atomic structure & periodic table, Chemical bonding and structure, Acid-base equilibrium and common Thermodynamic terms which could be explained by learning styles, and b) to identify learning styles best enhances students' academic performance in chemistry.

2. The second purpose of this study is to explore the role of chemistry instructional materials on students' academic performance in some fundamental concepts in chemistry among students with different and the same learning styles.

3. The third purpose is to integrate a specific learning styles model into the literatures of chemistry education and suggest how to apply it in the teaching-learning process of chemistry.

1.4.2 The research question

The main research question is: “How do learning styles and nature of instructional materials affect students’ academic performance in some fundamental concepts in chemistry among grade 11 and 12 preparatory school students?”

The sub questions are:

1. How well do Felder-Silverman’s learning styles predict academic performance in chemistry among preparatory school natural science students?
2. Which learning style best enhances students’ academic performance in chemistry: Visual or Verbal; Sensing or Intuitive; Active or Reflective; Sequential or Global learning styles?
3. How can students’ academic performances in chemistry be explained by instructional materials used in the preparatory schools among students :
   - A) with different Felder-Silverman’s learning styles?
   - B) performing extremely low or high on some fundamental concepts in chemistry
   - C) with the same Felder-Silverman’s learning style combinations?

1.5 Significance of the study

The study has both theoretical and practical contributions. Theoretically, it is set to design pedagogical model of chemistry that integrates learning styles and the nature of chemistry, and test if it relates to better students’ academic performance in some fundamental concepts in chemistry. From an applied perspective if learning styles successfully predict academic performance in chemistry, the study may provide empirical evidence or support about the learning styles that may lead to better performance in chemistry. Hence, it encourages chemistry education researchers to work on pedagogies/instructional approaches of chemistry that addresses both the nature of chemistry and types of learning styles.

Likewise, the study can inform the role of learning styles for students, teachers, and instructional designers in making informed instructional decisions by recognizing their learning styles profile as one background variable to consider. It may also bring new insight on how to produce suitable chemistry instructional materials and learning environment. Moreover, the study may also establish a platform for further research and be a stepping stone to other science researchers for in-depth understanding of how learning styles operates in chemistry and other science disciplines (e.g. Biology, Physics, etc).

Chapter-2

Theoretical framework

2.1 Introduction

The way learning styles integrate into chemistry instruction may enhance quality of chemistry education and students' academic performance in the subject. The theoretical underpinnings for the present work were derived from the study that aimed to understand students' learning styles by many academics in the field of learning styles (Cassidy, 2004; Dunn, 1984; Felder & Silverman, 1988; David A. Kolb, 1984), the pedagogical content knowledge (PCK) of Shulman (1986), tetrahedral metaphor of chemistry education (Mahaffy, 2004) and information-processing model for learning chemistry from audiovisual information (Tasker & Dalton, 2006).

This study was mainly informed by Felder and Silverman (1988) learning styles model for two reasons. The first reason is that, Felder and Silverman (1988) learning styles model has been developed for improving engineering education in general and chemical engineering education in particular. The second reason is that, Felder and Silverman's learning styles model appears closer to the actual classroom chemistry instructional practice. Because, according to Johnson (2006) and McCormack (1938) chemical engineering and chemistry have common origin and have some shared (similar) features of investigation and thought.

However, studies conducted based on Felder and Silverman's learning style model are slightly remote from chemistry education in the sense that they mainly focused on the learning styles profile distribution of engineering students and to some extent on science, technology and mathematics disciplines (Harvey et al., 2010; Paluo, 2006; Deonne, 2010). In short, there has been limited study investigating students' learning styles profiles in association with their academic performance in chemistry.

Felder and Silverman's learning style model defines learning styles in terms of learner's preference to receive (taken in) and process information (Felder, 1989). Therefore, Felder and Silverman learning style model comprised a category of information receiving and information processing learning styles (see Figure 2.1). The model has four dialectic dimensions: Visual/Verbal, Sensory/Intuitive, Active/Reflective, and Global/Sequential. The four opposite dimensions of Felder and Silverman learning styles model are derived from other learning style theories such as Dunn (1984), Feldman (2003), Kolb (1984), and others. In other words, these learning styles are directly related to; the perceptual modality (Visual/Verbal) and psychological (Global/Analytical) strands of stimuli of Dunn and Dunn's learning style models (Dunn, et al., 1995), Active/Reflective dimension of Kolb's learning style models (1984), Sensing/Intuitive dimensions of Jung's personality type theory (Lawrence, 1993).

Learning styles (Felder & Silverman, 1988; Feldman, 2003); the nature of chemistry (Gilbert & Treagust, 2009; Johnstone, 2006; Mahaffy, 2004; McNeil, 1996; Scerri, 2008), and information processing models of learning (Tasker & Dalton, 2006) could inform and shape instructional materials design and consequently student's preference to respond to instructional materials. Hence, understanding the type of learning styles in relation to the nature of a particular discipline can be a salient instructional element (Cassidy, 2004), to keep quality of science education. The current study was designed to investigate the types of learning styles and instruction that may impede or enhance academic performance in some fundamental concepts in chemistry. Accordingly, the conceptual frameworks of the most important variables operating in this study are mapped in Figure 2.1, and they are detailed in the following sections.

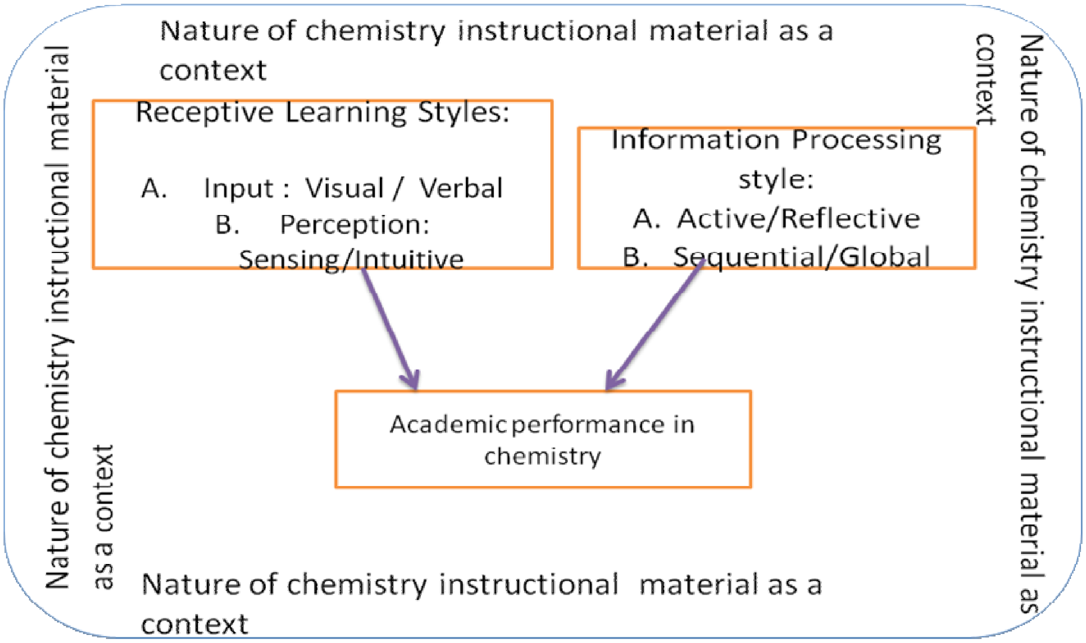


Figure. 2.1 Interactions between learning styles dimensions, and academic performance in chemistry

In this conceptual framework, the Active/Reflective dimension of Felder-Silverman learning styles includes the kinesthetic receptive dimension of Dunn and Dunn's Learning styles. As it can be seen in fig. 2.1, the researcher diagrammatically presented to show the expected relationship between the dependent variable (i.e. academic performance in chemistry) and the independent variables (i.e. Felder-Silverman's learning style dimensions) under a particular instructional context.

2.2 The nature of chemistry and its influence on instructional materials

According to Scerri (2008), chemistry has its own history, philosophy, nature and logical structure. Consequently, these unique nature and structure of chemistry influence chemistry education. As instructional material/information (e.g., chemistry instructional material) is organized and presented based on the nature and logical structure of the subject matter (McNeil, 1996). Chemistry instruction and instructional materials are expected to be unique and presented based on the nature of chemistry.

One of the specific features of a discipline is its unique representational nature. Regarding the unique representational nature of chemistry, many academics believe that chemistry works in three complex worlds namely the macroscopic (accessible to senses) explained by microscopic /molecular world (is not accessible to senses), and both worlds are conceptualized and represented by the symbolic world of chemistry (Rappoport & Ashkenazi, 2008; Talanquer, 2010 ; Treagust, Chittleborough, & Mamiala, 2003), see Figure 2.2. Each world of chemistry has different nature and lends itself to different ways of representation and explanation. For instance, in microscopic world of chemistry, the formal method that describes atomic orbital is mathematical expressions, but the pictorial representation is used for better understanding of atomic orbital (Barrett, 2001). Hence, instructional strategies for teaching atomic orbital or chemistry instruction in general may have special features compared to instructional strategies used in teaching other chemical concepts and disciplines.

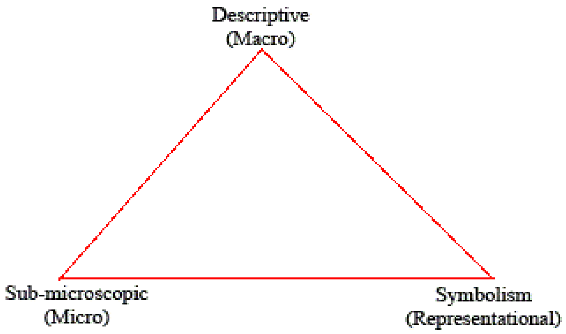


Figure 2.2 The Johnstone's Chemistry Triangle (Sirhan, 2007, p. 5)

Chemical representations are critical to learning chemistry (Wu, Krajcik, & Soloway, 2001). Owing to the multilevel chemical representations of chemistry, students face difficulties in interpreting and developing meaningful understanding (Chandrasegaran & Treagust, 2009; Talanquer, 2010 ; Wu, Krajcik, & Soloway, 2001). For instance, a two dimensional (2-D) representation of chemical structures demands students' mental rotations to transform the structures into three dimensional (3-D) representations (Wu, et al., 2001). As a result, students face difficulty in learning these multiple representations and complex nature of chemistry.

These multilevel chemical representations can influence instructional presentations (Danili & Reid, 2004; Tasker & Dalton, 2006). Instructional presentations in turn affect chemistry learning processes through sensory memory (input), perception filters (filters of the external environment), working memory capacity (processing role), and the long-term memory (encoding and storing) (Danili & Reid, 2004; Tasker & Dalton, 2006). Therefore, teaching or instructional presentations of chemistry need to match with sensory preferences and perception filtering criteria, and be within the working memory capacity of the learner (Hussein & Reid, 2009) to reduce the bottleneck effect of working memory on learning chemistry. The way these variables interact in chemistry learning process are depicted in Figure 2.3.

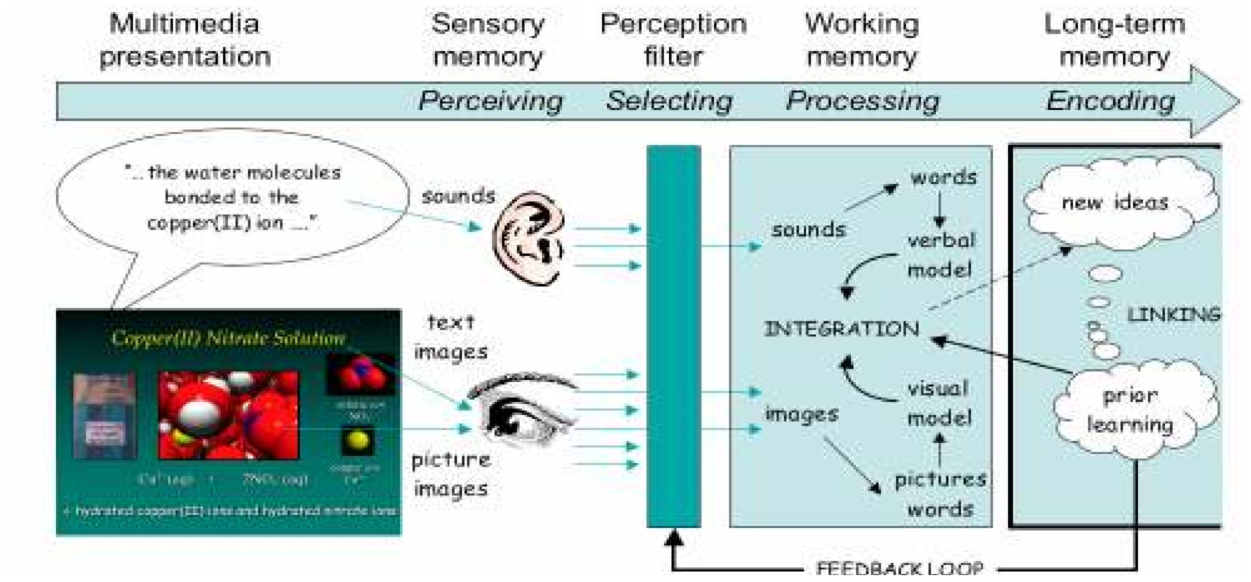


Figure 2.3 A multimedia information-processing model for learning from audiovisual information (Tasker & Dalton, 2006, p. 148).

Learning styles are characterized by the way learners perceive, process and retain new and difficult academic information, not by familiar and easy academic information (Dunn & Burke, 2008; Dunn & Griggs, 2000). Therefore, as can be seen in Figure 2.3, a perception filtering role to chemistry instruction may be played by learning styles. For instance, if the instructional material does not match with students' preference; the information passages through the perception filter may be hampered. As a result information processing and then the required learning may not be seamless. This tends to imply that students' to be successful in learning chemistry, chemistry instruction need to match with: 1) their learning styles/preferred way of learning, and 2) the logical structure, visual and conceptual information representations of chemistry.

Nevertheless, if the method of teaching chemistry does not take in to account the nature of chemistry, psychology of the learner and the working memory load demand, learning may become a difficult process (Hussein & Reid, 2009). Of course, if the natures of the topics are not difficult and do not cause working memory to be overloaded, the match or mismatch between learning styles and instruction of the topics may not cause learning difficulties.

2.3. Learning styles and its influence on instructional materials

Although different scholars possess different conceptualizations of learning styles, the common understanding is that every student possesses the capacity to learn but they do not have the same ways of learning (Ballone, 2001; Cullingford, 2004). For instance, in 1989 Dunn, Dunn and Price (cited in Milgram, Dunn, & Price, 1993) define learning style in terms of individual's reaction preference with 23 elements of instructional environment. According to Dunn, Dunn and Price, therefore students have different preferences to interact with the 21 instructional elements which they categorized in to five different strands of stimuli (Table 2.1).

Table.2.1. Individuals preferred ways of reaction to instructional environment (Dunn and Griggs 2002).

Physical environment		Social environment	Physiological environment	Psychological inclination	Emotional
Characteristics of each environment	Light, temperature, noise level, design	Learning alone, or with Peers, with adults, learning in combined way, being motivated by parent, by teacher,	Visual, tactile kinesthetic, and auditory preference , time of day, Energy highs and lows, intake, and mobility	Global/analytical, hemisphere preference, impulsive/reflective	Motivation, persistence, responsibility , and structure

Curry (1983) conducted a survey on 21 main learning style theories (Williamson & Watson, 2006). Then she grouped them in to three, like layers of an onion as it is depicted in figure 2.4.

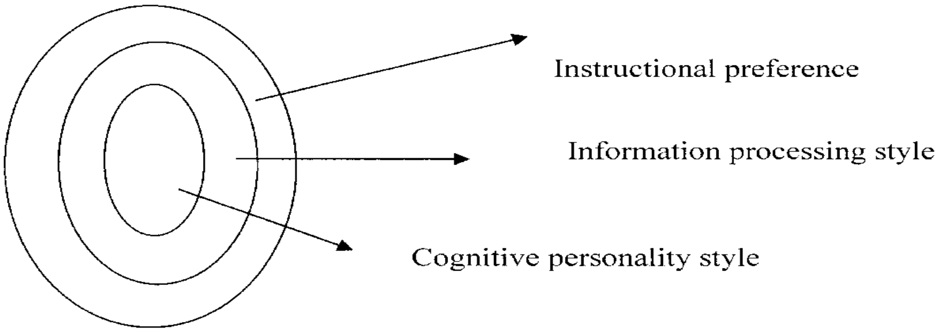


Figure.2.4 Depiction of Curry's (1983, p. 19) onion model of learning styles, (Linda, 2004, p. 682)

Each part of the layer describes one part of the learner's behavior (Linda, 2004; Williamson & Watson, 2006). Later Curry updated her model and further divided the third (the outer layer) to include theory of how social interaction impacts learning, and the fourth layer to refer to instructional preferences (Cassidy, 2004).

Felder and Silverman's (1988) dimensions of learning styles comprises some aspects of the cognitive personality styles, instructional preference and information processing styles of the Carry's layers of learning styles. Similarly, Feldman (2003:56) states that "learning style reflects our preferred manner of acquiring, using, and thinking about knowledge". Feldman further explained that we do not have just one learning style but a profile of styles. We all use variety of learning styles to receive information presented to us (receptive learning style), and to think on and learn most readily (information processing styles) from the received information (Feldman, 2003).

The receptive and information processing learning styles

Receptive learning styles

According to Felder and Silverman (1988), people have different strengths of Visual/Verbal and Sensing/Intuition receptive learning styles profiles. In different literatures, these receptive learning styles may alternatively be termed as sensory modalities or perceptual learning channels (Dobson; Feldman, 2003; Kratzig & Arbuthnott., Feb 2006).

According to Felder-Silverman (1988), Visual/Verbal learning style dimension refers to the preferred channel of input collection or stimuli. For instance, verbal learners prefer information presented verbally in written or auditory form, whereas visual learners take in information most effectively when it is presented visually in a diagram or picture form, such as chemical formula, and molecular structure.

The Sensing/Intuitive receptive dimensions of Felder-Silverman dimension may be referred as perceptual preferences. Sensing learners prefer to perceive concrete experiences, facts, details (uses sensory channels as source of data); whereas intuitive learners prefer to perceive abstract ideas, meanings, theories and imagination (i.e. do not prefer to use sensory channels to collect data for processing).

Information processing styles

Information processing learning styles directly related to the way we process information received through sensory modalities. The acquired information can be processed and transformed in to knowledge through information processing styles such as Active/Reflective style (Felder & Silverman, 1988; David A. Kolb, 1984), Sequential (Analytical) and Global (Relational) styles (Felder & Silverman, 1988; Feldman, 2003).

For example, students with most Analytical learning style learn most easily when they are first presented (taught) with information individually and principles behind a phenomena or situation (Felder & Silverman, 1988; Feldman, 2003). However, students with Relational/Holistic learning style learn readily when they are exposed to the full range of material (a big picture) first so that they break it down in to its component parts (Felder & Silverman, 1988; Feldman, 2003). Thus, to accommodate students with different learning styles instructional materials need to be designed not only based on the nature of the subject but also based on students' ways of learning styles.

Chapter 3

Literature review

3.1. Introduction

There are two main lines of debate and research concerning instructional variables related to characteristics of students' learning styles and nature of chemistry. The first emphasis of debate and research mainly focused on variables related to the nature of chemistry. Hence, a number of works related to the philosophy and nature of chemistry and how it influences chemistry teaching and learning process are intensively considered in the first part of the literature review section.

The second line of debate and research mainly focuses on the learner related instructional variable. Different works in this area place the learner at the center of the teaching-learning process, to the extent that the diversity of learners such as learning styles should be used for deciding content and instructional activities. Accordingly, the second part of the literature review is devoted to learning styles and their influence on educational activities.

Recently some efforts have been made to integrate the subject-centered approach and learner-centered approach (i.e. human element). For instance, Kolb (as cited in Coffield, Moseley, Hall, & Ecclestone, 2004) tries to integrate subject matter and learning styles by stating that "people choose fields that are consistent with their learning styles and are further shaped to fit the learning norms of their field once they are in it" p.64. Moreover, Justi and Gilbert (2002) stated that to be successful in teaching chemistry, teachers must have a good subject matter content knowledge and pedagogical content knowledge basis. Justi and Gilbert (2002) further explain that the nature of subject matter content knowledge is embedded within the scope of philosophy of chemistry, whereas the pedagogical content knowledge is embedded within the philosophical and psychological domain of chemical education.

3.2 Philosophy of Chemistry

According to Justi and Gilbert (2002) “The philosophy of chemistry addresses the scope of the phenomena that fall within the remit of chemistry, with the ontology of the entities of which those phenomena are thought to consist, and with matters of epistemology, the grounds of belief on which such knowledge rests” (p.213). Although, there are debates for philosophical independence of chemistry and on the reductionism of chemistry to physics, the philosophical debates are becoming a new pedagogical resource of chemistry teaching (Erduran, 2009; Lombardi & Labarca, 2007). Trends of works on the philosophy of chemistry also show that epistemologically or theoretically, chemistry cannot be reduced to physics (Lombardi & Labarca, 2007; Scerri & McIntyre, 1994). This in turn implies the remit of chemistry and its unique concepts, models, laws, and theories uniquely shape pedagogy of chemistry.

Lombardi and Labarca (2007) argue that due to the ontological dependence of chemistry on physics, physics is turn out to be a “fundamental” discipline, whereas chemistry is a phenomenological” discipline. In a similar line of thought many chemists emphasis that chemistry is “conceived as a ‘phenomenological’ science that only describes ‘phenomena’ which are apparent facts (Caldin, 2002; Lombardi & Labarca, 2007).

Tsaparlis, (2003) divides the phenomena into physical phenomena in chemistry (that involves changes of substances from one form or state to another) and chemical phenomena (that is a chemical change which involves a formation of new substances). Chemists engage in the world of chemical phenomenal through experimentation and explore the essential nature of chemistry to revise or develop their theories (Caldin, 2002; Scerri, 2000). According to the phenomenological view of the discipline, therefore the outer and observable phenomenological system of chemistry is highly susceptible to senses than intuition.

On the other hand, recognizing the two opposing metaphysical traditions: a substance philosophy and process philosophy, Schummer (2010) averted that philosophy of chemistry is a pragmatic and experimental science that combines both the process and substance philosophy. Substance philosophy claims that entities are permanent and it gives priority to entities or substances, whereas process philosophy claims that entities are in temporal state, and only changes are permanent and are given priority (Schummer, 2010).

Therefore, according to pragmatic philosophy of chemistry that combines both substance and process philosophy, chemistry characterizes and classifies chemical entities and substances, and describes changes that occur on chemical entities. In short, chemistry is concerned with characterizing substances (i.e. substance philosophy) and reactions (process philosophy) (Schummer, 2010).

To describe and communicate about chemical substances and changes, there is a need for a language or concepts of chemical substances that are most suitable for this purpose, (Schummer, 2010). Chemical concepts are the basis for communication among chemists and representing phenomenal world of chemistry. Erduran (2009) states that the philosophy of chemistry has linguistic contributions in communicating chemical knowledge. Erduran further elaborates that the language of chemistry characterizes the type of chemical discourse, signs and symbols used as tools in the representation of chemical knowledge. This implies that the natures of chemical concepts are distinct from concepts in other disciplines. Therefore, according to Erduran chemistry education should involve the teaching and learning of this system of chemical symbols and chemical discourse practices.

Like every other scientific discipline modern chemistry has a unique philosophy and it has fundamental concepts, methods and theories (Schummer, 2003, 2006). Vihalemm (as cited in Christie & Christie, 2003); Erduran (2009) and Scerri (2000) also stated that laws and theories of chemistry are different from those of classical physics. Erduran (2009) and Scerri (2001) further explain that, for instance the periodic law of chemistry is approximate unlike physical laws, such as Newton's laws of motion.

Schummer (2003, 2006) stated that chemistry has some unique and fundamental chemical concepts (such as element, pure substance, chemical species, compound, affinity, chemical reaction, atom, molecular structure and aromaticity), practical methods (such as experimentation, instrumentation, and chemical synthesis) and cognitive methods (such as pictorial language of chemistry, various forms of model building and representation), and chemical theories (theories, models and laws).

Correspondingly, Caldin (2002) identified some fundamental concepts in chemistry, such as: i) pure substances, ii) molecules, atoms, and subatomic particles, and iii) energy. According to Caldin, these fundamental chemical concepts can suggest modern structure of chemistry, and they are also milestones in the history of chemistry. For example, , Jensen (1998, pp. 679-680) in crafting the logical structure of chemistry, first categorized these fundamental chemical models and concepts into "composition/structure", "energy", "the role of time in chemical process" dimensions. And then Jensen approached each dimensions at molar, molecular and electrical levels of conceptualizations.

In sum, the fundamental concepts in chemistry can shape the structure and pedagogy of chemistry. For instance, the concept of molecular structure is fundamental to modern chemistry but it represents a non-existent objective reality at the quantum level (Scerri, 2000). Thus the different conceptual structures or logics of chemistry can imply different forms of representation and pedagogical techniques. As a result the pedagogical approach appropriate for teaching molecular structure may not be appropriate for teaching any aspect of quantum mechanical concepts.

3.2.1 The philosophy of chemistry in shaping the current chemistry education

The philosophy and nature of chemistry highly influences the 21st chemistry education. This is because of the fact that the object of study, theories and language of chemistry education as defined by ontological, epistemological and methodological views of chemistry should shape chemistry education. Thus, philosophy of chemistry has an important influence on the teaching of chemistry and chemistry education in general (Scerri, 2001).

There are influential chemistry education metaphors which have a philosophical origin. For instance, the Mahaffy's tetrahedral metaphor of chemistry education (Mahaffy, 2004, 2006), the Johnstone Chemistry Triangle (Johnstone, 2000; Sirhan, 2007; Talanquer, 2010) and Jensen logical structure of chemistry (Jensen, 1998) are some of the major influential models of chemistry education which have philosophical foundations or by the major extent influenced by the philosophy and nature of chemistry.

The macro, micro and symbolic world of chemistry introduced into the literature of chemistry education by Johnstone (Johnstone, 2000, 2004, 2006) can be conceived as the application of philosophy of chemistry in chemistry education (Erduran, 2005). Similar to Johnstone, Erduran

(2005, p. 167) states that one of the fundamental ways of thinking in chemistry is : “the interplay of the microscopic, symbolic and macroscopic levels”. This interplay between the microscopic and macroscopic level of chemistry is the subject of reductionism in the philosophy of chemistry.

Erduran (2005), and Scerri and McIntyre (2008) state that the relationship between the macroscopic and microscopic properties of matter is not symmetric. Scerri and McIntyre (2008) explain the relationship in such a way that two macroscopic systems which are “constructed from identical microscopic components are assumed to show identical macroscopic properties, whereas the observation of identical macroscopic properties in any two systems need not necessarily imply identical identity at the microscopic level” p.224.

The macroscopic property of water, for example is colorless. But its chemical properties at microscopic level (i.e. the nature of the atoms and bonds between these atoms) and the symbolic representations cannot be concluded from its macroscopic properties. On the contrary, the macroscopic properties of water can be explained by its microscopic identities. This suggests that the instructional presentations used to teach chemistry at the two levels are different.

Thus, the philosophy and nature of chemistry has been the foundations to some of the major chemistry education models forwarded by academics in the field. If this happens to be true, we can say that these chemical education models offer more emphasis to the nature of chemistry, which overwhelms students’ diversified nature (such as learning style) that may need equivalent importance for chemistry education.

1. *The nature of chemistry: As an argument for chemistry specific pedagogy*

The nature of knowledge is different across disciplines. The nature of chemical and physical knowledge, for instance is different and so is their respective education. According to Erduran and Scerri (2003) unlike physical knowledge, chemical knowledge mainly focus on qualitative explanations of matter, and chemical concepts are representations of classifications (e.g. element, compound, acid, base, etc.). In other words, epistemologically the description of matter is different for chemistry and physics. Chemical concepts highly rely on qualitative nature of matter, they are concerned with qualitative representations of matter. On the other hand, physical concepts are mainly dependent upon mathimatization. Therefore, such a unique nature and representation of chemical knowledge have strong pedagogical implications.

In the philosophical debates of science, philosophy of chemistry has identified four critical themes, such as reduction, laws, explanations, and supervenience (Erduran & Scerri, 2003). These four critical themes characterize chemical knowledge and show the distinct nature of chemical knowledge from physical knowledge (Erduran & Scerri, 2003). Erduran and Scerri, explains that chemistry cannot be reduced to physics, because chemistry focuses on system and interaction but physics focuses on individual components. Hence, the four critical themes raised in philosophical debates of science are important points to argue for chemistry specific pedagogy.

As Erduran and Scerri (2003) argue, some chemical concepts cannot be properly explained by laws of physics. Chemical composition, molecular structure and bonding are examples of chemical concepts representing chemical systems and interaction which couldn't be properly explained by physics laws. This is because the properties of chemical systems and interaction such as composition (i.e. the focus of chemistry) cannot be averaged by the property of individual atoms and molecules (i.e. the focus of physics). However, in physics the macroscopic properties of physical world is the average of properties of the microscopic properties. This proves that chemistry cannot be reduced to physics. Thus, it could be argued that the chemical concepts representing chemical system and interaction needs subject specific representations and pedagogy.

Another crtical theme that characterizes chemistry is the distinict nature of explanations that chemistry offers to chemical concepts (Erduran & Scerri, 2003; Scerri, 2000). For instance, chemical concepts such as bond formation, acid-base behavior, redox chemistry, electrochemistry, reactivity are examples of chemical concepts explained in terms of electrons exist in electronic orbitals (Erduran & Scerri, 2003). But ontologically, orbital and electronic configuration are a non-existent reality in quantum mechanics (Erduran & Scerri, 2003; Scerri, 2000). Therefore, these useful explanatory natures of electronic orbitals given by chemistry have important pedagogical significance in teaching and learning of these chemical concepts.

Moreover, laws in chemistry have not the same predictive powers like laws in physics. Hence, the distinct nature of chemical laws such as periodic table has an important pedagogical implication. For example "periodic law do not follow deductively from a theory in the same way in which idealized predictions flow almost inevitably from physical laws" (Erduran & Scerri, 2003). Approximate predictions emanate from periodic laws are based on some initial conditions and assumptions. Consequently the pedagogy of teaching laws in chemistry and teaching laws in physics needs to be distinct. And hence to support students leaning of chemical laws, classroom instructional practices need to be designed based on the distinct nature of chemical laws.

Finally, another critical theme that distinguishes explanation in chemistry from physics is supervenience. Supervenience refers to a relation of asymmetric dependence between the properties of the macroscopic system and microscopic identities, (Erduran & Scerri, 2003; Scerri & McIntyre, 1994). For example, if two macroscopic systems are constructed from identical microscopic entities in the same fashion, they are believed to show identical macroscopic properties. However, if any two macroscopic systems have the same properties, it does not necessarily imply identical identity at the microscopic level. Two substances having the same smell may not necessarily mean that they are constructed from identical microscopic identity but the converse may hold true. Thus, the view of asymmetric dependence (supervenience) suggests chemistry specific pedagogy that considers the asymmetric nature of the macroscopic and microscopic worlds of chemistry.

The other factor that can affect the pedagogy of chemistry is its knowledge structure. Different disciplines can be characterized by different knowledge structures. Concepts in a discipline and their relationships in a particular subject characterize its knowledge structure (Donald, 1983). For example, the knowledge structure of chemistry refers to the logical organization of chemical concepts and models (G. Green & Rollnick, 2006). Similarly, Taagepera and Noori (2000) and Green and Rollnick (2006) explained the structure of chemistry in terms of the sequence of chemical concepts.

Chemical knowledge structure is attempted to be described by different scholars. Jensen (1998), for instance suggested nine characteristic categories for chemical concepts and models forming the structure of chemistry. In spite of different descriptions about the structure of chemistry, the fundamental structure of chemical knowledge is different from physics (G. Green & Rollnick, 2006). The knowledge structure of chemistry is mainly characterized by modeling, but physics is by mathematical applications (G. Green & Rollnick, 2006). In a similar attempt, De Vos et al in

Jensen (1998) regarded key chemical concepts as concepts that represent chemical substances or chemical reactions.

The learning structure of a subject plays a key role for knowledge retention and transfer (Donald, 1983). As it is discussed in the foregoing paragraph, learning structure of chemistry is mainly influenced by the logical structure of chemistry in turn by its philosophy. Hence, the researcher can surmise that the learning structure of chemistry can influence teacher's chemical knowledge structure and appropriate pedagogy to teaching chemistry that the teacher should apply. In this regard, Goodstein and Howe (1978) stated that "In every chemistry teacher's mind there is a complex structure of the discipline with hypotheses, theories, and philosophies interlocking to produce a supporting framework for facts" p.171. Donald (1983) noted that if instruction is based on the knowledge structure of a particular subject area, learning can be enhanced. Therefore teaching-learning process in chemistry can be suggested and improved by understanding the 'structure of chemical knowledge' (Donald, 1983; Erduran & Scerri, 2003).

2. ***Representational nature of chemistry and their influence on chemistry instruction***

Knowledge about the world has a representational nature (Greca & Moreira, 2000) and it has an epistemological origin. Though ontologically chemistry is reduced to physics, epistemologically it is distinct from physics and its chemical knowledge or explanations are level specific (Lombardi & Labarca, 2007). Chemical knowledge or explanation at macroscopic level is specifics to this level, or it is not transferable to microscopic and symbolic level. For instance, explanations given to copper wire are specific to copper wire. It is not applicable to explain copper atom.

Although explanations at the three levels of chemical representations are unanimously converged in explaining chemical phenomenon (Rappoport & Ashkenazi, 2008), the asymmetric relationship between the properties of macroscopic system and microscopic identity is maintained. For example, according to Gilbert & Treagust (2010) the macroscopic level or phenomenological types of chemistry refers to a simplified representation (i.e. exemplar to complex reality under study) of the empirical properties of matter at different states. Gilbert & Treagust (2010); Talanquer (2010); and Treagust, et al. (2003) further explain that representation of matter at the macroscopic level (i.e. in the laboratory) refers to the actual phenomena of matter or our world (i.e. the daily or laboratory activities) that is the most concrete and observable or perceptible to senses and extension of senses. For instance color, smell, phase change, etc are examples of the observable behaviors of chemical world that can be managed and manipulated.

While the macroscopic world of chemistry represents the properties of phenomenon/material, the microscopic world of chemistry offers justifications to the observed properties of the material world. In other words, the microscopic world of chemistry represents the particulate nature of matter (i.e. electrons, atoms and molecules) and used for explaining the macroscopic level or the material world in terms of movement of the particles (Treagust, et al., 2003).

Although the microscopic entities of chemistry are powerful tools for explaining the perceptible level of reality, they are not perceptible to senses (Gilbert & Treagust, 2009) and they can only be represented through the use of models (Harrison & Treagust, 2000; Wu, 2003). Hence, the microscopic level of chemistry has been alternatively represented by terms such as “explanatory level, the particulate theories and models of matter, and submicroscopic chemistry" (Talanquer, 2010 p. 3).

In the realm of chemistry, chemists use symbolic representations as their language or means of communication about the macroscopic and microscopic levels of chemistry. Chemical equations, mathematical expressions, pictures, graphs, analogies, molecular models, and symbols are some examples of symbolic representations for both macroscopic and microscopic level of chemistry (Treagust, et al., 2003). For instance, atoms, molecules, charges, electrons, bonds, etc are microscopic level realities and have symbolic representations, whereas solid (s), liquid (l), gas (g), temperature (T) are examples of macroscopic level properties along with symbolic representations (Gilbert & Treagust, 2009). These three levels of representations indicate how chemical representations also shape the chemistry instructional practices.

3. *Nature of Models in chemistry and their influence on instructional practices*

According to Silberberg (2010) a model is a simplified version (i.e. not exact copy of nature) of matter and it can be used to make predictions about related phenomena in nature. "Model is a caricature of nature" (Thomas, Lohaus, & Brainerd, 1993, p. 1). Model simulates the reality to easily and systematically explain, describe, and explore phenomena (Barnea & Dori, 2000; Gericke & Hagberg, 2010). Model bridges the gap between scientific theory and nature (Gilbert, 2004) by presenting typical identity of the represented reality (Harrison & Treagust, 1998).

Similarly Bailer-Jones (2002) defines a model as an explanatory description of a phenomenon that facilitates perceptual and intellectual access to that phenomenon. Models are methods, products of science, and the common tools of knowledge representations, whereas modeling is the "essence" of scientific thinking (Harrison & Treagust, 1998).

Moreover, a scientific model is built to represent a complex, abstract and unobservable properties of entities of reality and it is built by considering some very relevant variables and assuming the unobservable properties of entities (Lombardi & Labarca, 2007). “Such abstract entities are the *models* of a real system; for instance, a model of a real pendulum is constructed by disregarding friction, or a real gas is modeled as a collection of hard spheres interacting according to the laws of elastic collision” (Lombardi & Labarca, 2007, p. 188). Lombardi & Labarca (2007, p. 189) also stated that “the direct reference of a scientific theory is not a real system but a model of systems”, that is “the links between scientific theory and reality are always mediated by a model”. A reality cannot be represented by a single model; it can be represented by multiple models (Lombardi & Labarca, 2007).

“A model is a system of related concepts” (Gericke & Hagberg, 2010, p. 606), These systems of concepts have an epistemological origin. Similarly, chemical models and modeling are guided by the epistemology of chemistry and are specific to the nature of chemistry. Failure to distinguish the difference of laws, theories and models of chemistry with other disciplines may introduce serious misconceptions (Scerri, 2001).

Chemical models are context sensitive; they are not like fundamental laws of physics. It means that different chemical models may be used at different contexts or levels to explain the same chemical phenomenon (Scerri, 2000). For instance, there is no consistent explanation given for the relative occupation and ionization of 4s and 3d orbital of transition metals. That is 4s orbital is preferentially occupied and ionized than the 3p orbital (Scerri, 2000).

Moreover a single chemical fact/phenomenon can be explained at the macroscopic, microscopic, and symbolic level and each level may require different chemical models (Chandrasegaran &

Treagust, 2009). These macroscopic and microscopic levels representations in turn contribute to complexity of chemistry. Particularly the molecular/microscopic level of chemistry is beyond human senses that can only be explained and understood by the use of models (Wu, et al., 2001). This suggests that teaching different chemical models representing the same chemical fact may require different pedagogical model than the type of pedagogical model applied in teaching physics.

Chemistry instructional materials therefore require to be designed to present natures of different chemistry concepts, laws theories and models. The presentation of these chemical contents through instructional materials could be at macroscopic or microscopic or symbolic level of chemistry in a balanced manner or based on psychological readiness of learners. According to Treagust and Chittleborough (2001), learning chemistry is a matter of understanding representations of chemistry. Consequently, understanding chemistry would mean and understanding the representations of chemical contents through chemistry instructional materials because,

3. 2. 2 Chemistry instructional materials and its implications for learning chemistry

Instructional materials as the objects of learning might be difficult to design in a way that considers both the learner's difference and the nature of the subject matter. According to McLoughlin (1999), individual differences such as learning styles present profound challenges to instructional design. With this challenges in mind, McLoughlin (1999) argued that the quality of instructional material is determined by its suitability to a large number of student population's learning styles.

However, Nottis and Kastner (2005) argue that chemistry is difficult for students not only due student related variables but also due to its multi-level contents, and nature of instruction. For example, a study on Sophomore students in which one group was taught group symmetry through lecture method and the other one was taught through computer by keeping prior knowledge as a co-variate) found that there wasn't significant achievement difference between the two groups (Nottis & Kastner, 2005). In short, the lecture method and computer assisted instruction failed to be reflected in students' achievement difference.

The same research reported that over half (50%) of each group prefers to use other instructional approaches and concluded that there was a mismatch between learning and instructional styles (Nottis & Kastner, 2005). Of course, the research didn't report whether the remaining (<50%) students' learning styles matched with teaching styles or not.

On the other hand, Stodolsky and Grossman (1995) stated that subject matter plays a central role to influence high school teachers' perception about the curriculum and teaching-learning process, and the actual instructional practices. According to the cognitive load theories, the cognitive load that is imposed by the intrinsic complexities of the materials to be learned (for instance the intrinsic complexities of chemistry) is not a function of instructional design (Sweller, 1994), but it is the function of the nature of the subject matter.

Chemistry is a complex subject which works in three chemical worlds and could induce an intrinsic cognitive load on chemistry instructional materials. Therefore, learning Chemistry is difficult, because it requires exposure to the three modes of chemistry representation: the molecular, the symbolic and the macroscopic levels. In order to ease chemistry learning, instructional materials should present the three modes of chemical representation. However, multiple representation of chemistry can be one possible sources of intrinsic cognitive load of instructional design. For example, the macroscopic, microscopic and symbolic level description of combustion of charcoal is an intrinsic complexity which is induced by the multilevel of chemistry. Therefore the nature of chemistry is also important variable in the teaching-learning processes.

3.3 Conceptualizations of learning styles

Learning style is an individual signature of everybody (Dunn, Beaudry, & Klavas, 2002). However, learning styles is not a univocal concept. Regardless of enormous progresses made in the field of learning style, there is not a single consensual definition or macro-level theory to describe learning styles. Of course, the different definitions and explanations of learning styles have commonalities and unique qualities (Dunn & Griggs, 2000). If one looks at the dictionary meaning of the term learning style, it stands for individual differences in the way that people prefer to learn (Frisby, 2005; Learning style. Encyclopedia of Educational Psychology," 2008 ; Learning styles.Encyclopedia of Giftedness, Creativity, and Talent," 2009). It is further described that learning styles is a unique pattern that individuals use to approach information processing or learning situation. Frisby (2005) explains that the way people think, learn, and process information is unique and often influenced by their attitudes, feelings, and preferences. Hence, teachers and/or classroom instruction needs to be individualized and sensitive to different learning styles.

Although many learning style theorists concur with the idea that students learn easily and effectively when instructional environment met with their learning style (Dunn, et al., 2002; Rita Dunn, Jeffery S. Beaudry, & Klavas, 2002; Rochford, 2003; Woolhouse & Blaire, 2003), there are more than 70 different models and theories that describe the kind of individual differences and the way these differences influence learning ("Learning style. Encyclopedia of Educational Psychology," 2008).

Literary learning style has different definitions and explanations forwarded by different educators and experts in the field. For instance, some describe learning styles in terms of learning process and learners characteristic and preferred ways to take in and process information (Litzinger, Halee, Wise, & Felder, 2007)). Others use the term learning styles and cognitive styles alternatively (Cassidy, 2004; Desmedt & Valcke, 2004; Valley, 1997). Valley (1997) defines learning styles as the preference that an individual have to process information in a particular way when carrying out learning activities. Still others explains it in terms of students preferred way of interaction to external environment/stimuli such as (Dunn, et al., 1995; Dunn, et al., 2009).

In general, literatures show that there are more comprehensive and loose, narrower and focused definitions and models of learning styles. Some workers try to put more comprehensive and looser definitions to learning styles. For instance, according to Duff (2001); Fatt (2000); Felder and Brent(2005); and Shell, et al.(2010) learning styles are described as the characteristic cognitive, affective, and psychological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment.

Shell, et al.(2010) maintain the comprehensive description of the concept of learning styles by stating the presumption that human beings are different in the modality of stimuli in which they learn best (i.e. take in, remember and process new information). Similarly, others such as Arthurs (2007), and Dunn and Griggs (2000) extended the definition of learning styles to include the learners' cognitive, affective, psychological, physiological and social patterns (i.e. pattern referred to learning style) that determine their academic performance.

Dunn and Griggs further justified that many theorists such as (A. Y. Kolb & Kolb, 2005; David A. Kolb, 1981) focus only on a single or two variables in bipolar continuum. However, others argue that

> *the complex nature of learning suggests that a multidimensional model is required to reflect the many individual differences resulting from each person's biological, developmental, and psychological experiences. A multidimensional concept of learning style is the basis of the three comprehensive models (Dunn & Griggs, 2000, p. 8).*

Moreover, there are theorists who assume that learning style is a biologically and developmentally imposed personal characteristic (Dunn, et al., 2002). Accordingly, Dunn and Griggs (2000) stated that most people are affected by 6 to 14 number of learning styles. It means that some students may be influenced by as many as 14 different types of learning styles variables while others may be influenced by as few as 6 learning styles (Dunn & Griggs, 2000). Hence, applying the same teaching method may be effective for some students but ineffective for others (Dunn, et al., 2002).

As it is stated in Dunn & Griggs (2000) if many learning style variables are not incorporated in learning style definitions and models, the learning styles variables that contribute significant gain to some students may remain untreated. Thus, the broader concept of learning style that includes cognitive functioning and indicates general preferences for methods and environments for learning (Arthurs, 2007) can have more educational significance. Furthermore, Dunn and Griggs (2000) states that as learning has a complex nature, it suggests multidimensional learning style models to reflect individual differences that may arise from the biological, developmental and psychological experiences.

Dunn and Burke (2008), and Dunn and Griggs (2000) explain that learning style is characterized as the way that each learner begins to concentrate on, process, absorb, and retain new and difficult academic information. The way learners interact with new and difficult academic information (i.e. concentrate on, process, absorb, and retain new difficult academic information) is different for everyone (Dunn & Burke, 2008). This definition of learning style tends to suggest that the match or mismatch of science instruction to learning styles may have little or no impact for success in learning easy or familiar subjects but for the difficult ones.

There are different learning styles models and theories which attempts to describe learning styles and how learning styles shape education (Cassidy, 2004). For example, there are more than 70 frequently mentioned learning style models (Coffield, et al., 2004; Hadfield, 2006). The Cassidy's onion model, Kolb's model, Dunn's model, Jung's psychological types, Felder and Silverman model are some of the most comprehensive learning style models consulted in the current study. These learning style models and theories are important to explain students preferred way of learning and how it influences students' academic gain.

3.3.1 The Kolb's model and implications for science education

The origin of Kolb's learning styles model is experiential learning theory derived from the works of prominent academics: John Dewey, an educational theorist; Kurt Lewin, social psychologist, and Jean Piaget, developmental psychologist (A. Y. Kolb & Kolb, 2005; Rainey & Kolb, 1995; Towns, 2001). Experiential learning theory (ELT) defines learning as the process whereby knowledge is created through the transformation of experience (Coffield, et al., 2004; deJesus, Almeida, & Watts, 2004; Koob & Funk, 2002). Hence, knowledge results from the combination of grasping and transforming experience" (A. Y. Kolb & Kolb, 2005, p. 194).

According to Kolb, learning is a cyclical process of experiences which involves concrete experience, reflective observation, abstract conceptualization, and active experimentation (Coffield, et al., 2004; Garnett, 2005; Koob & Funk, 2002; Rainey & Kolb, 1995). In this experiential theory of learning, there are two dialectically related modes of grasping and transforming experiences: 1) Concrete experience to Abstract conceptualization continuum on the y-axis, and 2) Reflective observation to Active experimentation continuum on the x-axis (Azevedo & Akdere, 2010; A. Y. Kolb & Kolb, 2005; Kvan & Yunyan, 2005; Towns, 2001).

In the four cycles of learning process, the concrete experience is the bases for observation and reflection, which is assimilated and distilled into a new abstract concept (generalization) that will be accommodated and ready for action and active experimentation (deJesus, et al., 2004). At each stages of the situation students develop a tendency to some preference (referred as learning styles) over others (deJesus, et al., 2004).

Garnett (2005) and deJesus, et al. (2004) described that people who prefer to grasp and learn through concrete experience are more interested in active involvement, relating to other people and learning by doing. Whereas people who prefer to grasp and learn through abstract conceptualization is opposite to concrete experience. They prefer to learn through active conceptualization (i.e. through application of thought and logic), and able to plan, analyze and develop new concepts and theories (deJesus, et al., 2004; Garnett, 2005). The information grasped either through concrete experience or abstract conceptualization can be transformed into knowledge through reflective observation or active experimentation. For instance, people who prefer to transform experience through reflective observation like to watch, listen, take a variety of views, brain storm and discover meaning (deJesus, et al., 2004; Garnett, 2005). On the contrary those who prefer active experimentation best suit to learning situation that allows to try and experiment new concepts and theories (deJesus, et al., 2004; Garnett, 2005).

Out of the experiential theory of learning, Kolb identified four learning styles (i.e. divergent, convergent, assimilator, and accommodative) with specific characters (deJesus, et al., 2004; Garnett, 2005; David A. Kolb, 1984) (see figure 3.1). Divergent learner is characterized by the combination of reflective observation and concrete experience (i.e. RO + CE) (deJesus, et al., 2004; Garnett, 2005). Divergers prefer to see situations from different perspectives, brain storm, tend to be imaginative, emotional, innovative and social/art loving (deJesus, et al., 2004; Garnett, 2005).

There are people who are opposite to divergers and described as convergers. Convergers characterized by combinations of abstract conceptualization and active experimentation (i.e. AC + AE). Such kinds of learners are more focused, use deductive reasoning and single solution oriented problem solving approach, appear to be unemotional and enjoy science subjects (deJesus, et al., 2004; Garnett, 2005).

The other dialectical dimension of Kolb's learning styles are assimilators and accommodators. Assimilators are characterized by the combination of reflective observation and abstract conceptualization (i.e. RO + AC). Assimilators prefer to learn through inductive reasoning, and like abstract concepts more than people and or concrete experiences (deJesus, et al., 2004; Garnett, 2005). Thus, they prefer to learn mathematics and science (deJesus, et al., 2004; Garnett, 2005). Accommodators prefer exactly opposite to assimilators. They are characterized by combination of active experimentation and concrete experience (i.e. AE + CE). Accommodators learn best by doing things, carrying out plans, performing experiments, novel or concrete experiences and social interactions (deJesus, et al., 2004; Garnett, 2005).

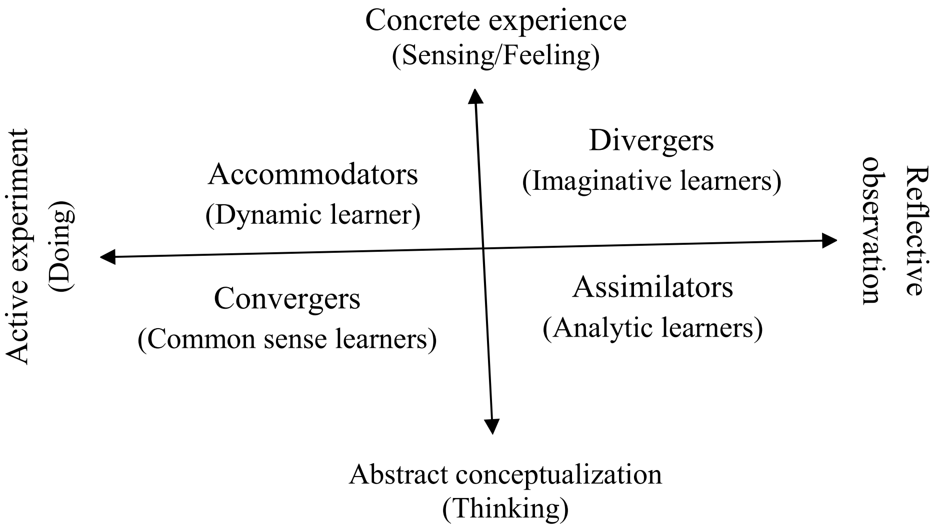


Figure 3.1 The four learning styles of Kolb: Divergers, Assimilators, Convergers, and Accommodators (Towns, 2001, p. 1108)

Research reports on the effects of Kolb leaning styles on education

A longitudinal study that measured engineering students' dominant learning styles showed that most students were assimilators whereas least number of students were accommodators (Cagiltay, 2008; Hargrove, et al., 2008). The study by Cagiltay (2008) showed that most assimilator and converger engineering students performed better than accommodators and divergers. The ANOVA and "post hoc comparisons using the Dunnett's C-test" showed that only assimilators' and divergers' academic performance scores was statistically significant (Cagiltay, 2008, p. 420). Similarly, Hargrove, et al.(2008) reported that convergers achieved the highest GPA than divergers, but this GPA difference was not statistically significant. In general, all engineering major students' GPA variation with learning styles was not statistically significant (Hargrove, et al., 2008).

3.3.2 Jung's personality type theory

When we go back to the origin of personality type, Jung had observed human behavior and identified a pattern and he called it "psychological types" (Lawrence, 1993, p. 7). Jung explained psychological type as the way people prefer to perceive and make judgments (Lawrence, 1993). According to Lawrence (1993) "what comes into consciousness, moment by moment, comes either through the senses or institution. To remain in consciousness, perceptions must be used. They are used - sorted, weighed, analyzed, evaluated -by the judgment processes, thinking and feeling" (p. 7).

Jung first identified two basic types of attitudes (extraversion and introversion); and then two opposite types of mental functions or conscious activities (i.e. two opposite functions of perception: sensation (now sensing) and intuition; and two opposite types of functions of judgment: thinking versus feeling) (Quenk, 2009). Based on works of Jung's "psychological types", Briggs observed an individual difference in the way habituating to the external world and added a "Judging versus a Perceiving attitude toward the outer, extraverted world" (Quenk, 2009, p. 2).

In 1943, Briggs and Myers also developed and published an instrument to quantify and/or measure Jung's psychological type. This instrument is called Myers and Briggs Type Indicator (MBTI). The "Judging versus a Perceiving" attitude dimension of MBTI is not considered here. Because, it is not linked to Felder-Silverman's learning style model.

1. The opposite perception process/ activities: Sensing versus Intuition

The perceiving process helps to interact with the outside world either through Sensing or Intuition. Sensing refers to the way of observing information/ the observable realities (such as the macroscopic worlds of chemistry) through the senses (Borg & Shapiro, 1996; Lawrence, 1993). Lawrence (1993) describes that if a person is mainly Sensing, he or she has sharp power of observation, learning facts and details to view the reality objectively.

Lawrence further explains that Sensing learners predominantly prefers to begin from practical and known experiences, and move step-by-step to link new facts with past experiences and test practical importance. Here at this point, it is important to remember that the chemical world as a phenomenal world can be sensed and understood through measurement or observations (Caldin, 2002; Scerri, 2000). For instance laboratory works, models and other concrete experiences present the chemical world as it exists or closer to the objective reality. In this case Sensing type learners may become advantageous in practical chemistry classes.

Unlike Intuition, Sensing type highly depends on and prefers direct experience and doing things than playing with theories and abstracts. People with Sensing preference collect evidence through the five senses, and learn/or memorize facts and details with less conscious effort (Quenk, 2009). Therefore, instructional materials may need to provide concrete experiences and support Sensing learners to perceive information easily for further processing.

On the contrary, Intuitive learners preferentially enjoy perceiving abstract information. "The sensing function S ‘‘include(s) all perceptions by means of the sense organs’’ (p. 518), whereas the intuition function N ‘‘is perception by means of the unconscious’’ (Wilde, 2011, p. 8). According to Quenk (2009), an Intuitive learner focuses on "patterns, meanings and future possibilities which are implicit in the current study". Therefore, Quenk (2009) makes clear that concepts, ideas, theories, and inferring connections among diverse pieces of information are perceived effortlessly by Intuitive learners. However, if Intuitive learners are presented with facts, details and concrete experiences they may face difficulty of perception unless they invest a considerable mental effort.

According to Quenk (2009), the Sensing(S)-Intuition(N) perception dichotomy has multi-facets. Quenk explained that " Analyses of the multifaceted Sensing-Intuition items of the MBTI questionnaire have identified five pairs of opposite facets: Concrete (S) versus Abstract (N); Realistic (S) versus Imaginative (N); Practical (S) versus Conceptual (N); Experiential (S) versus Theoretical (N); Traditional (S) versus Original (N)" p.6. Quenk explained each opposite facets as follows.

2. *The opposite mental functions of judgment: Thinking (T) versus Feeling (F)*

Information collected through perception process will be processed for decision either through thinking (T) or feeling (F) judgment functions (Lawrence, 1993). Lawrence (1993) says that "Thinking (T) is the term used for a logical-decision making process, aimed at an impersonal finding"; whereas, "Feeling (F) is a term for process of appreciation, making judgments in terms of a system of subjective, personal values" p.8. Similarly, Wilde (2011) explains thinking as decision making process that involves intellectual cognition to reach logical conclusions, but feeling function makes decision as a function of subjective valuation. According to Lawrence (1993), thinking types are attracted to areas that need tough-mindedness and technical skills, whereas feeling types are attracted to areas that need interpersonal skills than technical skills.

Quenk (2009, p. 6), states that "thinking judgment applies a specific criteria and principle for a linear and logical analysis of Sensing and Intuitive data". Hence, thinking type people analyze the available information/fact objectively and logically in step-by-step manner with a minimum mental effort (Lawrence, 1993; Quenk, 2009). It is only after thinking, Quenk (2009) further elaborates that conclusion is arrived at the issue of subjective value or issue of welfare and harmony with people is considered by applying considerable conscious effort.

Similarly, the feeling judgment applies specific criteria and principle to analyze and conclude on the Sensing and Intuitive data. Feeling type applies logical principles to the available data but this principle works only if the decision maximizes the harmony and well-being of people and situations (Lawrence, 1993; Quenk, 2009). In short, all values for the well-being of people, connections, and passions are the governing principles or pillars of feeling decisions.

As he did for Sensing-Intuitive dichotomy, Quenk (2009) analyzed the multi-faceted Thinking-Feeling items of MBTI instrument and identified five pairs of opposite facets of Thinking-Feeling dichotomy. As Quenk (2009) explains the multi-facets of Thinking-Feeling are: "*Logical (T) versus Empathetic (F); Reasonable (T) versus Compassionate (F); Questioning (T) versus Accommodating (F); Critical (T) versus Accepting (F); Tough (T) versus Tender (F),*" P.*7.* At this moment, it is important to observe the similarity that exists between thinking types and Sequential/Analytical learners; and feeling types and Global/Holist. For instance, like thinking types, Sequential learners prefers to use a linear thinking process and incremental step-by-step learning preference (Litzinger, et al., 2007). Similarly, feeling type prefers to uses Global/Holistic thinking process and learn in large leaps (Litzinger, et al., 2007).

3.3.3 Felder-Silverman learning style model and its relation for other learning style models

The study of different learning style models demonstrates that Felder-Silverman's learning styles model is originally built up on other learning style models like Jung, Kolb, Dunn and others. For instance, the four bipolar dimensions of the Felder-Silverman's model are more similar to Jung's type theory. The Jung's type theory classified all conscious mental activity into perception process and judgment processes (Lawrence, 1993). This classification is in accordance with Felder-Silverman's definition of learning styles as a way to take in and process information (Felder & Silverman, 1988). But, a slight difference exits when details of Jung's type theory and Felder-Silverman model is examined.

In Jung's theory there are two perception process (Sensing and Intuitive) and two judgment process (thinking and feeling). The Sensing/Intuitive dimension of Jung's type theory is the same as Felder-Silverman Sensing/Intuitive learning styles dimensions. And a thinking/feeling dimension of Jung's theory is almost similar to Sequential/Global dimensions of Felder-Silverman learning styles model except some slight terminological and meaning differences. Hence, Felder-Silverman learning style model included perceptual modalities or channels of information intake (Visual/Verbal) and information grasping/processing modalities (Sequential/ Global, and Active/Reflective) dimensions. The Visual/Verbal and Sequential/Global dimension of Felder-Silverman learning styles are derived from Dunn's learning styles model (Dunn & Burke, 2008); whereas, the 'Active/Reflective' processing dimension is a component of Kolb's learning styles model (Felder & Silverman, 1988). The refined Felder & Silverman learning style dimensions and corresponding teaching styles are presented in Table 3.1.

Table 3.1 Dimensions of Learning and Teaching Styles (Felder & Silverman, 1988, p. 675)

Preferred learning styles	Corresponding teaching styles
Sensory Intuitive Perception	Concrete Abstract Content
Visual Verbal Input	Visual Verbal Presentation
Active Reflective Processing	Active Reflective Student participation
Sequential Global Understanding	Sequential Global Perspective

Sensory/Intuitive perception: A Sensory learner prefers to perceive information that comes through their five senses in existing ways, concrete, practical and structured forms with careful details or oriented towards facts and procedures (Crutsinger, et al., 2005; Felder, 1989; Felder & Silverman, 1988; Lawrence, 1993; Mcpherson, 1999). On the other hand an Intuitive learner prefers to use new/innovative ways, and perceive information internally through memory and imagination (Felder, 1989). Mcpherson (1999) describes that Intuitive learners choose to perceive the world as " possibilities, meanings, and relationships, relying more on personal hunches or insights rather than on five senses " P. 47. Intuitive learners enjoy abstract or conceptual materials oriented towards theories and underlying meanings not with careful details and concrete experience (Felder, 1989; Felder & Silverman, 1988; Graf, Viola, Leo, & Kinshuk, 2007).

Visual/Verbal learners: Visual learners prefer to perceive information presented in the form of pictures, diagrams, flow charts, demonstrations and any other visual presentations whereas Verbal learners prefers to learn from written materials and spoken explanations and they face difficulty with visual styles (Felder & Silverman, 1988; Graf, et al., 2007; Palou, 2006a). For instance, laboratory works, chemical formulas, two-and-three dimensional representations of chemical objects and processes may provide fertile learning environment for Visual learners, whereas theoretical models and conceptual explanations may provide fertile learning environment for Verbal learners.

Active/Reflective learners: An Active learner prefers to learn by doing, experimenting, and interacting working with group ideas, and they are social oriented; but a Reflective learner enjoys learning by thinking alone and processing internally, and they are impersonal oriented (Felder, 1989; Felder & Silverman, 1988; Graf, et al., 2007).

Sequential/Global learners: Learners may process globally or sequentially to understanding materials (Crutsinger, et al., 2005). Sequential learners preferentially use a linear, logical and step- by-step learning (sequential progress) and/or thinking processes and they enjoy from detailed and parts to whole presented materials, but the converse is true for Global learners. Global learner perceive, process and think the overall picture of the material, intuitively and learn things holistically starting from whole (non-sequential progress) not from component parts (Felder, 1989; Felder & Silverman, 1988; Graf, et al., 2007). According to Crutsinger, et al. (2005), Sequential learners receive information and get understanding of material as a ‘connected pieces of information’, whereas Global learners receive a holistic picture of information and understand the material by looking at relationships, and relating to prior knowledge and experiences.

Felder-Silverman learning styles model and implications for science education

Palou (2006) states that a good starting point for every teacher to improve the effectiveness of teaching is to understanding the different ways students perceive and process information. Thus, in order to understand engineering students' different ways of perceiving and processing information, and create a suitable learning environment that match with learning preferences, Felder and Silverman proposed a four dimensional learning styles model.

Felder & Brent (2005) affirms that there are variables which may have important implications to the teaching and learning processes. These instructional variables can fall into three main categories of diversity: learning styles, approaches and intellectual developments levels. Here learning style is described as the characteristic way of taking in and processing information (Felder, 1989; Felder & Brent, 2005; Felder & Silverman, 1988; Litzinger, et al., 2007). Students have different strength or preferred ways of taking in and processing information (learning styles). As a result, the way information presented may impact student's learning differently.

Learning involves the information reception and processing steps. That is students first receive the external information (through senses) and then process it internally or they may ignore it (Felder & Silverman, 1988). Accordingly, the material (information) may be learned or may not be learned (Felder & Silverman, 1988). In this regard, Felder-Silverman learning styles model presents details of how different learning styles preferences influence the process of learning starting from information perceiving to processing.

In connection to the multiplicity of students' learning styles, there is a presumption that no learning style is better than the other, and no one best instructional approach fits to all sorts of learning styles (Felder & Brent, 2005). However, one instructional approach may best serve a particular type of learning styles. For instance, Felder and Silverman (1988) states that engineering students' drop out, poor performance, and disinterest in engineering courses or curriculum can be attributed to the mismatch between instruction and learning styles strength. Therefore, according to Dubetz, et al. (2008) to reduce students' academic problem/challenge, information presentation or instruction needs to consider all sorts of learning styles

Researches on the influence of Felder-Silverman learning styles on mathematics, science, engineering and technology disciplines

Although understanding students' learning styles may be one step in improving teaching; its relation or match to the nature of subject matter should also be another important instructional variable to be considered. There are some empirical studies which attempt to present the relation between Felder-Silverman and other related learning style models with nature of subject matters/ disciplines. For instance, Crutsinger, Knight, and Kinley (2005) stated that the majority of merchandising students' learning styles profile were Active, Sensing, Visual and Sequential. Another study by James-Gordon and Bal (2001) also showed that engineers at the design department of automotive company were significantly Visual learners. This implies that instructional environments for engineers at automotive company in design department should be designed in the ways that predominantly match with their Visual learning styles.

According to survey study of literatures on learning preference of electrical and computer engineering technology (ECET) students, "ECET students were Active, highly Visual, and Sequential learners" (Harold Broberg, et al., 2006, p. 40). The study also considered learning styles of students at different matriculation levels and found a link to discipline selection and retention (Harold Broberg, et al., 2006). A similar learning styles preference distribution (. 89.85% Visual, 67.4% Active, 81.6% Sensor, 55.1% Sequential) was observed among Mexican food science and engineering students (Palou, 2006) and with the majority of merchandising students of Southwestern University (Crutsinger, et al., 2005). In fact, the study didn't consider why Visual, Active, Sensor and Sequential learners do favor merchandising, food science and engineering disciplines and how their performance was as compared to Verbal, Reflective, Intuitive, and Global learners. Moreover, it did not show who performed better in these disciplines.

According to Hal Broberg, Lin, Griggs, and Steffen (2008), there has been an implicit assumption that both engineering technology and engineering students have similar learning styles. Of course, disregarding some differences of learning styles distribution across and within engineering disciplines the overall learning styles distribution among technology, engineering and science students were similar (Harvey, et al., 2010).

However, the comparison between the survey of the distribution of learning styles of engineering technology students and surveys of the distribution of learning styles of engineering students showed a significant variation in learning style distributions (Hal Broberg, et al., 2008; Harvey, et al., 2010). For instance, the engineering technology students' preference for Sensory learning over Intuitive learning was significantly higher by a considerable margin than for engineering students (Harvey, et al., 2010). Even the data on students' matriculation within survey results showed notably higher retention of Sequential learners for engineering technology students (Hal Broberg, et al., 2008). Hal Broberg, et al (2008) explains that the variations and similarities of learning styles between the engineering technology and the engineering disciplines were attributed to variation in subject matter and teaching methodology.

Similarly, a comparative study designed to show learning styles distribution of students of science, technology, engineering and mathematics disciplines reveals some pattern of similarity and variation. For instance, Harvey, et al.(2010) and Palou (2006) reported that the overall learning styles profile patterns of science, technology, engineering and mathematics students were found Visual, Active, Sensual and Sequential. However, the study still showed significantly different learning styles distributions among the disciplines in some learning style dimensions. For instance, mathematics and engineering students were different in Visual/Verbal and Sequential/Global dimensions (Harvey, et al., 2010). A similar pattern of variation was observed among the learning styles of engineering and chemistry students, and within different types of engineering disciplines students (Harvey, et al., 2010).

Within engineering students, for instance, in Active/Reflective learning styles dimension, civil and industrial engineers were more Active learners than other engineering students, but there were higher number of Reflective learners in industrial engineering (Harvey, et al., 2010). In Sensing/Intuitive dimension, computer science students were found Intuitive while other engineering students were found Sensing (Harvey, et al., 2010). And in Sequential/Global dimension, chemical engineering and computer science students were more Global than other engineering students, but there were lower number of Sequential learners in computer science (Harvey, et al., 2010).

Although, these studies show how learning styles were distributed across and within science, technology, engineering and mathematics students, they did not addressed the type of learning styles which helped them to excel academically in each disciplines. For instance, a study by Deonne (2010) reported that learning styles in general and in Sequential learning styles in particular along with resilience variables enhance academic persistence in engineering programs. However, Deonne (2010) didn’t say anything about the other dimensions of learning styles and didn’t explain why Sequential learners were persistent in engineering programs .

3.3.4 Research reports on the role of learning styles on chemistry performance

Krause (1997) designed an experimental study at Clemson University to investigate the effect of Jung’s personality type based learning styles on general chemistry performance. In the study, the treatment group received learning styles matched instruction but the control group didn’t receive such kind of instruction. The study revealed that Sensor/feeler and Intuitive/feeler learners performed significantly lower than other learning styles students. On the other hand, Sensor/thinkers performed significantly better than others (Krause, 1997). However, according to Lawrence (1993) physical sciences research people are inclined to be Intuitive and thinking (NT) type. According to Lawrence (1993), Sensing and thinking:

> “People are mainly interested in facts, since facts are what can be collected and verified directly by the senses-by seeing, hearing, touching, etc. And they make decisions on these facts by impersonal analysis, because the kind of judgment they trust is thinking, with its step-by-step process of reasoning from cause to effect, from premise to conclusion” p. 240.

Recently, correlational studies at Sydney University conducted by Yeung, Read, Robert, and Schmid (2006) and Yeung, Read, and Schmid (2005) did not report the influence of Sensing/Intuitive (S/N) learning styles on students’ chemistry performance. But, they reported that introvert and thinking (I/T) students performed better than extrovert and feelers (E/F). Lawrence (1993), uses the term Reflective for introverts and Active for extraverts. According to

Lawrence (1993), introverts (Reflective) interest turn out to the inner world of ideas and private things whereas extraverts (Active) turn out to the outer world of action, people, and things. When the finding of Yeung, Read, Robert, and Schmid (2006) and Yeung, Read, and Schmid (2005) is interpreted in terms of Felder-Silverman learning styles model, Reflective and Sequential students seems to perform better than Active and Global learners.

An inquiry by Deratzou (2006) revealed that Visual learners understand chemical structure and bonding and perform better if they get Visual training and practice. Deratzou further explains that visualization would improve Visual abilities such as visualizing chemical structures and using models that offer the way to think about chemical concepts. But, Deratzou didn't consider all the 4-dimensions of Felder-Silverman learning styles (Visual/Verbal, Sensing/Intuitive, Active/Reflective, and Sequential/Global) and didn't show the extent of relation between Visual learning styles and learning chemical concepts and/or performance if visualization training and practice were not employed.

Recently, Al-Jaroudi (2009) conducted a causal-comparative study to see the relationship between the 4-dimensions of Felder-Silverman learning styles and pre-service elementary teachers' conceptual understanding of chemistry and the nature of matter in a simulated learning environment. In this study, no significant relationship was reported between learning styles and achievement gain (Al-Jaroudi, 2009).

Al-Jaroudi's study was conducted in a simulated learning environment which could put Visual learners at advantage (Al-Jaroudi, 2009). Although, a simulated learning environment was presumed to provide favours for Visual learners, Al-Jaroudi's report did not show the success of Visual learners. Moreover, the study didn't explain why significant relationship was not observed between Felder and Silverman learning styles (at least the Visual learning styles supported by simulation) and achievement gain in chemistry. The Al-Jaroudi's (2009) causal-comparative study revealed a conflicting result with others findings such as Deratzou (2006), Harvey, et al. (2010), and Krause (1997). Therefore, the current study was conducted to expand Al-Jaroudi's study and examine the role of Felder-Silverman learning styles on students' academic performance in some other fundamental chemical concepts.

In conclusion, the foregoing paragraphs suggest instruction materials to be designed neither based only on the mere analysis of the material nor based only on the mere analysis of learner related variables. Rather, they suggest instruction materials to be designed based on the analysis of both the subject matter and learner related variables. Therefore, any information required to be learned shouldn't be designed without taking the knowledge of the learner and the characteristics of the material into account (Sweller, 1994). If an instructional material is designed based on the mere analysis of either of the two, it may not be supportive to learning.

In this connection, a new paradigm of thinking called "pedagogical content knowledge", first introduced by Shulman (1986) states that the pedagogical competency of a teacher and instructional strategies are content or subject specific (Boz & Boz, 2008; Bucat, 2004). Pedagogical content knowledge (PCK) combines the knowledge of pedagogy and disciplinary subject matter (Bond-Robinson, 2005; Park, Jang, Chen, & Jung, 2011; Shulman, 1986). Bond-Robinson (2005) explains that chemistry as a discipline has its own pedagogical content knowledge that could help to improve instructional materials and then to promote chemistry learning. Therefore, research work towards developing PCK of chemistry which attempts to integrate learning style and nature of chemistry is worthwhile.

Chapter 4

Research Methodology

4.1. Research Paradigm and Design

4.1.1 Paradigm

This study was designed based on the pragmatism research paradigm. In contrast to positivism and interpretivism, pragmatism is an eclectic and flexible research paradigm that mixes methods (Feilzer, 2010). According to pragmatists, the measurable aspect of the classroom reality is closely related to existentialist reality, which refers to an experiential world with different elements or layers: some objective, some subjective, and some a mixture of two (Feilzer, 2010). The different layers of phenomenon can be described through measurement or words which will be improbable to do by a single paradigm. In this study, therefore to measure the relationship between learning styles and chemistry performance (i.e. an objective layer of the study) and to explore the role of student's instructional experience that could determine their academic performance in chemistry (i.e. the subjective layer of the study), a pragmatist paradigm that mixes both the quantitative and qualitative methods was best suited world view of the current study.

4.1.2 Research design

The research design applied by the current study was a sequential explanatory mixed method design (Quantitative → qualitative) (Hanson, Creswell, Clark, Petska, & Creswell, 2005; R. B. Johnson & Onwuegbuzie, 2004 ; Kelle, 2006; Towns, 2005). A sequential explanatory mixed method design is "particularly useful for, as its name suggests, explaining relationships and/or study findings, especially when they are unexpected" (Hanson, et al., 2005, p. 229). Moreover, Ivankova, Creswell, and Stick (2006a) stated that:

> *In the sequential explanatory design, priority, typically, is given to the quantitative approach because the quantitative data collection comes first in the sequence and often represents the major aspect of the mixed-methods data collection process. The smaller qualitative component follows in the second phase of the research, p.9.*

Therefore, this study was conducted in two phases: a quantitative study followed by a qualitative study (see Figure 4.1).

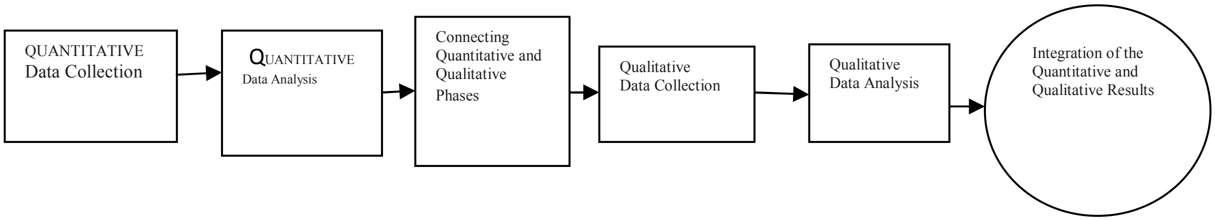


Figure 4.1 Sequential Explanatory Design Procedures (Ivankova, et al., 2006a, p. 16).

The purpose of the quantitative phase of the study was to predict students' academic performance on some fundamental concepts in chemistry on the topics: Atomic structure & periodic table, Chemical bonding and structure, Acid-base equilibrium and common Thermodynamic terms from Felder-Silverman's learning style and to identify the learning styles which contributes more to academic performance on these chemical concepts. To achieve the purpose of quantitative phase of the study, a correlational design was applied. A correlational research design is useful particularly to address a number of complex educational variables (such as achievement and learning style) and their relationships without changing the more realistic setting, (Gay & Peter, 2003; Louis, Lawrence, & Keith, 2000).

The qualitative phase of the study was to be connected (see Figure 4.1) by purposively selecting participants (with different or the same learning styles, and who had extreme low or high performance on the test) from samples in the quantitative phase of the study. The aim of the qualitative phase was to explore the role of instructional materials on students' academic performance on some fundamental concepts in chemistry. Moreover, deviations of the results (unique results) of the quantitative part of the study (i.e. such as observation of students with the same learning but performed extremely different) were also described in some depth. Finally, the findings of the qualitative and quantitative phases (see Figure 4.1 & Figure 4.2) are connected at the interpretation and discussion stage of the research process (Hanson, et al., 2005; Ivankova, et al., 2006a).

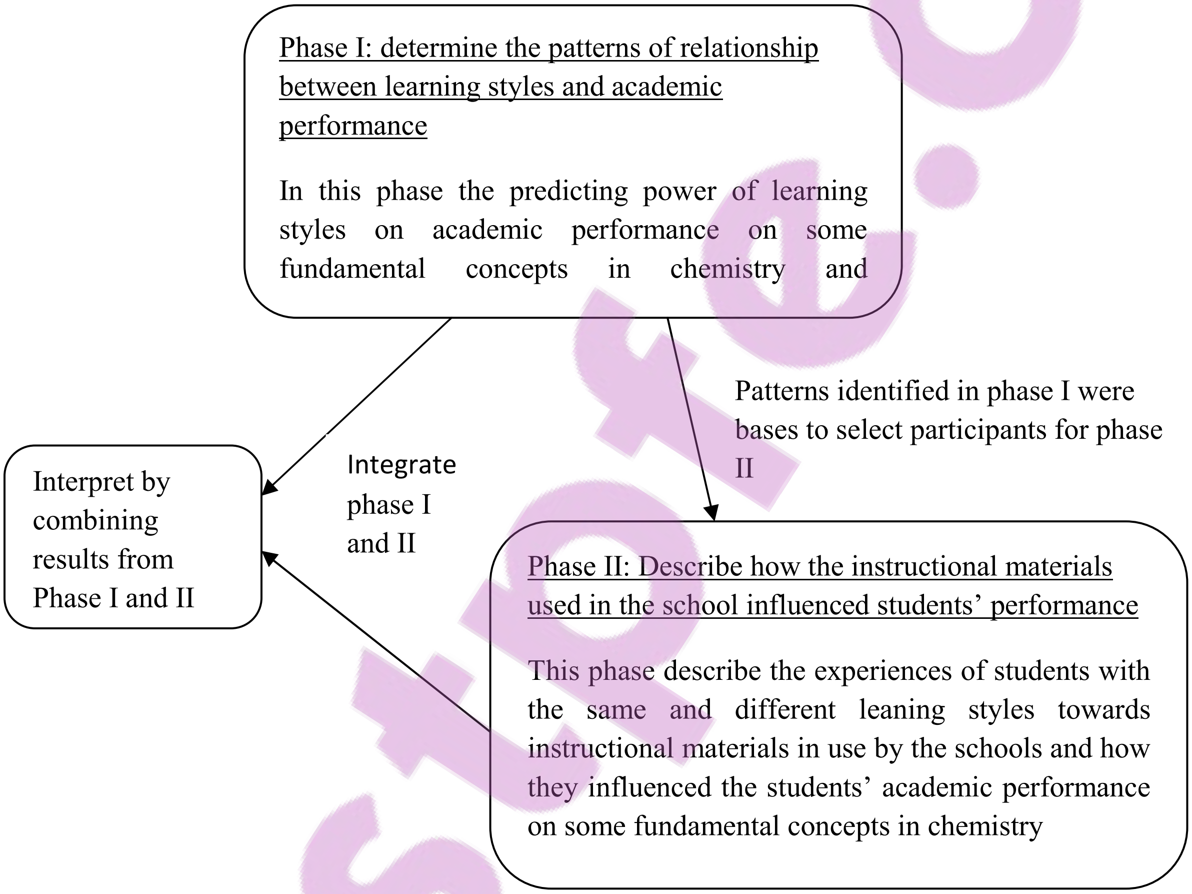


Figure 4.2 represents the two phases of the study and show how they relate to each other

4.1.3 Instructional context of the study area and Population

1. Instructional context of the Study area

The study area was located at two preparatory schools in North Shoa administrative zone of the Amhara regional state. More specifically, preparatory school "A" is located at 130 km, while preparatory school "B" is located at 190 km North of Addis Ababa, Ethiopia. This study was conducted in preparatory schools for two major reasons. One, the purpose of this study was to predict academic performance on some fundamental concepts in chemistry from Felder-Silverman's learning style. The other purpose was to explore the role of instructional materials on academic performance in some fundamental concepts in chemistry among students with different and the same learning styles. Many of these fundamental concepts in chemistry were widely covered in preparatory school chemistry curriculum.

Moreover, the fundamental chemical concepts in the preparatory school's curriculum were mainly taught through the same nationally designed curriculum, standardized instructional materials such as standardized student's chemistry textbook prepared at national level, televised instruction from the same national center (Plasma TV instruction). The classroom teaching-learning process was facilitated by first degree chemistry teachers who are guided by the same syllabus and teacher's plasma TV guide. Moreover, students in both preparatory schools do not have adequate access for practical works.

In sum, the abundant coverage of the fundamental concepts and the same instructional settings in the preparatory schools to teach these fundamental chemical concepts compared to instructional settings in colleges and universities were more standardized and provided me better opportunity to achieve the purpose of the current study. Moreover, all students in the participating schools had rural and urban origin and similar cultural background and are from the same administrative zone. Thus it is possible to loosely conclude that students in both schools were assumed to experience similar social and instructional experience or academic settings. This further offered a fertile ground to conduct the study in the preparatory schools found in the Administrative zone.

2. Population of the study

Populations of the study were grade 11 and grade 12 natural science stream students of two preparatory schools. The number of students in grade 11 was 902, and the number of students in grade 12 was 774. This suggests that members of population of the study are different in terms of their grade level.

The unit of analysis for this study was an individual student from grade 11 and grade 12 natural science preparatory school students. The approximate age range of these groups of students was from 17 to 20 years. The groups of students at this age range in Ethiopia, therefore, can give their consent by themselves to participate or not participate in the study.

Observation of students' academic record in their respective grade level revealed the existence of some variations in their levels of academic performance. It means that students in the populations were not homogenous in terms of the academic status for various reasons. One is that, in the Ethiopian education system, a high school education has two cycles: first cycle secondary schools (Grades 9 and 10) and second cycle secondary schools (usually called as preparatory schools or Grades 11 and 12). Students who completed their first cycle secondary school education are admitted to preparatory schools either in natural science or social science streams if they fulfilled the admission requirement. Although, a minimum score of 2.0 points in the Grade 10 national examination is required for admission into the preparatory schools, the

Ministry of Education would on annual basis set an admission requirement based on the availability of space in the preparatory schools. The maximum score points expected in the Grade 10 National Examinations is 4.0 points. Therefore, the composition of preparatory school students in terms of their performance level as measured by Grade 10 National Examination ranges 2.0 to 4.0. From these population characteristics, I have learned that population of the study (i.e. students in the two preparatory schools) were heterogeneous in terms of their level of performance on Grade 10 National Examination and their current performance level in their respective grade levels.

4.2 Research methods

4.2.1 Sample design and procedure

The sequential mixed method design with nested sampling strategies was applied (Collins, Onwuegbuzie, & Jiao, 2006). Nested sampling refers to a sampling procedure in a way that the sample members selected for one part of the study represents the subset of participants selected for the other component of the study (Collins, et al., 2006).

The minimum expected sample size for the quantitative phase of the study were decided statistically using a software called G*power. Therefore, the sample size taken for each grade level (i.e. grade 11 and 12) were computed using G*power. According to the output of G*power calculation for a linear regression prediction model with a power analysis: medium effect size (f^2) =0.15, α=0.05, and 4 predictor variables (i.e. Visual/Verbal, Sensing/Intuitive, Active/Reflective, and Sequential/Global), the minimum required sample size was 151. Leech, Barrett, and Morgan (2005) also made clear that the sample size for multiple regression study can be estimated by the formula: 50 + 8 k or 104 + k, where k stands for the number of independent variables. On the basis of this formula, the sample size for this study was expected to be 50 + 8x4 = 74 or 104 + 4 = 108. Although the output of G*power was 150, to minimize non-response rates the researcher took a sample size of 167 from grade 11 students and 159 from grade 12 students. Because in correlational research design, such sample size is enough to keep external validity (Fraenkel & Wallen, 2005).

Sample sizes for each grade level were decided independently. It is because, the tests used to measure academic performance of grade 11 and grade 12 students on some fundamental concepts in chemistry were designed from fundamental concepts in their respective grade levels. Therefore, the sample size for each grade level was taken independently.

A stratified random sampling technique was employed to select 167 participants from grade 11 and 159 participants from grade 12 students of the total population. According to Louis, et al. (2000), stratified sampling involves dividing the population into homogemeous groups in that each group containing subjects with similar characteristics. Accordingly, the heterogenous population by academic performance level were stratified into three categories. The stratifications of the population were made based on students' academic performance in their schools (i.e. academic performance measured by the average scores of a student in their specific grade level). Thus, students in both schools were stratified into three strata: high performer (3rd quartile or the upper 25%), medium performer (inter quartile range or the middle 50%), and low performer (1st quartile or the bottom 25%) group of students. The size of students in grade 11 and 12 were different. To get a representative sample of each grade level the researcher used a disproportionate stratified random sampling technique. Therefore, a total of 167 participants from grade 11 and a total of 159 participants from grade 12 students were selected from each stratum.

For the qualitative part of this study, participants were selected from samples in the quantitative phase of the study. In sequential mixed method design, the methodology and results of the first phase informs the methodology employed in the second phase (Teddlie & Yu, 2007). Because, the final sample in the first strand of the study can be a sample frame for the second strand (Teddlie & Yu, 2007). Moreover, "the quantitative part of a sequential quantitative-qualitative design can guide systematic case comparison in the subsequent qualitative inquiry by helping to identify criteria for the selection of cases and by providing a sampling frame" (Kelle, 2006, p. 308). Therefore, this design can help to reduce the size of the scope of samples and overcome an important threat for validity of qualitative research that researchers focus on remote and marginal cases (Teddlie & Yu, 2007).

Consequently, for the qualitative phase of the study a total of 16 participants were selected from the samples in the quantitative phase of the study. These participants were selected based on their 1) consent to participate, 2) extremely high or low performances on some fundamental concepts in chemistry and having the same learning styles combinations, 3) extremely high or low performances on some fundamental concepts in chemistry but with different learning styles combinations. Extreme cases (i.e. extremely high and low performing students) were identified from the descriptive statistics in phase one. As a result, 11 participants were selected from school "A" and 5 participants were selected from school "B". However, a total of 15 participants, that is 10 participants from school "A" and 5 participants from school "B" were participated. One participant withdrew from the study for personal reasons.

4.2.2 Data collection Instruments

In the quantitative phase of this study, to answer the data collection instruments that were used research questions 1, 2 and 3 were Amharic version of Felder-Soloman's Index of learning styles (ILS), and a multiple choice chemistry test/tasks. The Amharic version of Felder-Soloman's Index of Learning Styles (ILS) was used to identify students' learning styles. Whereas their academic performance on some fundamental concepts in chemistry were measured using multiple test. Because, according to Burton, Sudweeks, Merrill, and Wood (1991) multiple choice test is appropriate instruments to measure different educational objectives and apply in many subject areas. It is also easy and efficient to administer. Andrews (2012) stated that the reliability and validity are essential qualities of a test for evaluation. Therefore, Andrews (2012) reported that the coefficient of internal consistency reliability of multiple choice test is higher than for essay.

The multiple choice items of the chemistry tests/tasks are designed from selected areas of chemistry topics in each grade level chemistry syllabus which were covered in the first semester. The chemistry topics were selected based on fundamental concepts in chemistry identified from literature on the philosophy of chemistry (Appendix A) and based on the emphasis given in the curriculum, and the extent of difficulty of the topics as pointed by experienced school teachers. It was literatures on the philosophy of chemistry that helped the researcher to identify some fundamental concepts in chemistry that could form the logical structure of the discipline.

In the qualitative phase of the study, to answer research questions 4 and 5 a qualitative data were collected using Amharic version of a semi-structured and open-ended questionnaire along with oral explanations of each questions on a face to face basis.

The reliability and construct validity of the ILS

According to Felder and Spurlin (2005), the test-retest reliability research reveals that ILS has high and statistical significant correlation. Moreover, Livesay et al. in Zywno (2003) found that ILS has relatively high test-retest reliability in repeated measurements over time, and concluded that the ILS was an appropriate and statistically acceptable tool for characterizing learning preferences.

Different authors reported that, the English version of Felder and Soloman Index of Learning Style (ILS) has an acceptable level of construct validity and inter-consistency reliability for research purposes (Felder & Spurlin, 2005; Ku & Shen, 2009; Litzinger, et al., 2007; Litzinger, Lee, Wise, & Felder, 2005; Zywno, 2003). Moreover, Zywno (2003) states that if cut-off value for Cronbach's alpha (α) is greater than 0.5, it is acceptable for attitude tests.

The level of difficulty of the English version of the ILS questionnaire was evaluated by 12 students, whose academic record in the school ranges from low to high and then translated into Amharic. These students were not participants of the study. Most of the students reported that the languages of some ILS items were difficult. And they suggested that it should be translated into Amharic language, in which they were fluent in writing and speaking through Amharic.

Consequently, the English version of ILS was translated into Amharic language by retaining its psychometric characteristics through triangulation of the translations. In other words, the ILS instrument had been translated into Amharic by one documentary linguistic and culture PhD student, and one psychology lecturer. Following the translation I compared the two Amharic versions of ILS were compared and finally the Amharic version of ILS was produced. And then the researcher (I) arranged discussion for 20 minutes with both the PhD student and psychology lecturer to refine it well. At last the final Amharic version of ILS was given to English lecturer to translate it back into English. Then the two English versions of ILS were compared and found consistent.

In the end, the final Amharic version of ILS was piloted on 25 students and the reliability coefficients (Cronbach alpha) were computed. The pilot study revealed that a Cronbach alpha coefficient of Visual/Verbal was 0.73, Sensing/Intuitive was 0.73, Active/Reflective was 0.68 and Sequential/Global was 0.64. These reliability coefficients show that for each dimension, the ILS was greater than the cut-off value 0.5. Thus, it has acceptable level of reliability for research use. Moreover, the comparison of reliability report (alpha values) for the Amharic version and English version of ILS was nearly the same (see Table 1 below).

Table 4.1 Comparison of the alpha values of the English version and the translated Amharic version of ILS

Acti-Refle.	Visual- Verb	Sens-Intui	Seq-Glob	N	Source
0.60	0.74	0.77	0.56	572	(Litzinger, et al., 2005)
0.61	0.76	0.77	0.55	448	(Litzinger, et al., 2007)
0.68	0.73	0.73	0.64	24	(the current pilot study)

The table shows that the alpha values for ILS to measure each dimension of Felder-Silverman learning styles were similar and were above 0.5.

Reliability and validity of the multiple item chemistry tests

Chemistry tests for measuring academic performance on some fundamental concepts in chemistry were carefully constructed from the fundamental concepts of chemistry in grade 11 and 12 chemistry syllabus. According to Caldin (2002) and Schummer (2003, 2006) some fundamental concepts in chemistry are: pure substance, chemical species, compound, affinity, chemical reaction, atom and subatomic particles, molecules and molecular structure, practical method (experimentation), energy, chemical theories, and cognitive method of chemistry (pictorial language of chemistry, model building & representation).

Therefore, to construct the test, the researcher identified some fundamental chemical concepts from the topics included in the first semester of grade 11 chemistry syllabus and in the first semester of grade 12 chemistry syllabus (see Appendix A). The chemistry test for measuring academic performance of grade 11 students was constructed carefully from fundamental chemical concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure in grade 11 chemistry syllabus (see Appendix A: table 1 & 2). Moreover, the chemistry test for measuring academic performance of grade 12 students was constructed carefully from fundamental chemical concepts in the topics: Acid-base equilibrium and common thermodynamic terms in grade 12 chemistry syllabus (see Appendix A: table 1 & 2).

To ensure content validity of the test items the relative proportion or number of items constructed from each topic was calculated based on the weight given to each of them, and their relative weigh were determined by proportions of periods allotted to each topic (Gronlund, 1977). That is:

$$\text{total number of items per topic} = \frac{\textit{number of items in the test x periods allotted for the topic}}{\textit{the total number of periods for topics in which the test is constructed}}.$$

After the test was constructed it was validated by two experienced chemistry teachers who were teaching in both grade levels in preparatory school “A” and one experienced chemistry teacher who was teaching in both grade levels in preparatory school “B” and my supervisor (chemistry educator).

Before administration, each test was piloted on 25 students in other preparatory schools at their respective grade levels and KR-20 was computed. The computation of KR-20 reliability test showed that the reliability index for the 21-item chemistry test used to measure grade 11 students’ academic performance on some fundamental concepts in chemistry was .90. Similarly, the computation of KR-20 reliability test showed that the reliability index for the 22-item chemistry test used to measure grade 12 students’ academic performance on some fundamental concepts in chemistry was .87. Therefore; this indicates that the tests were reliable enough to measure students’ academic performance on some fundamental concepts in the aforementioned chemistry topics.

Semi-structured and Open-ended Questionnaire

To examine the role of chemistry instructional materials on students’ academic performance, the researcher designed a semi-structured and an open-ended questionnaire accompanied by oral explanations (see appendix B). The language clarity of the questionnaire was evaluated by one Amharic lecturer and two preparatory school students. And then the researcher sat together with the lecturer and students, and discussed on the clarity of the questionnaire. Moreover, while participants were filling the questionnaire the researcher was with the participants if further explanations were needed by them. In other words, the questionnaire was designed to be filled on a face to face basis in the office of chemistry department for giving explanations to participants when the need arises.

4.3 Procedures of the study

The study had commenced with a first round research site visit to communication with districts level education offices (Zone and woreda) and permission request. I received permission and support letter from Amhara National State Education Bureau, North Shoa Education Department, Curriculum Preparation and Implementation Core Business process to conduct my study (see Appendix F). Thereafter, through negotiation with school principals, deputy principals, teachers and students about the purpose and action plans of the study, I reached at an agreement with them on how and when to administer the test and ILS.

The chemistry tasks/tests were constructed and validated by a pool of experts of chemistry education and experienced chemistry teachers. The ease of understandability of the English version of the ILS questionnaire was checked by 12 preparatory school students and three chemistry teachers. Accordingly, the ILS was translated into Amharic language. The appropriate time to administer ILS instruments and the questionnaire was arranged by negotiating with students and the schools. Then, the quantitative data was collected and analyzed using SPSS. Based on the results from quantitative data, the qualitative data was collected and analyzed. Finally the findings of the two strands of the study were integrated and full version of the report was presented.

Administration of the Index of Learning styles (ILS), and chemistry test and semi- and open-questionnaire

For school “A”, I scheduled a convenient time and identified classrooms in collaboration with chemistry teachers and the psychological counselor of the school. The classroom and the schedule were communicated to students by me together with chemistry teachers and the counselor through the schools’ mini media or orally in their classes. For school “B”, I discussed with the school’s deputy director and two chemistry teachers of the school and arranged appropriate time and classroom. In general in both schools the instrumentation program was set not to clash with the regular school program.

Procedures of ILS administration

Before administering the ILS, oral description was given to teachers and students about the ILS and the benefit of completing the questionnaire. Students were also told that their dominant learning style type planned to be communicated and advice will be given to them on how to select and use instructional materials that matches to their learning styles. They were also advised to carefully fill in the ILS questionnaire and choose the alternative that could best describe or spelt their self.

Procedures of chemistry test administration

In both schools the chemistry test was administered as part of their examination by their teacher to help students feel that they were engaged in the test mood. Chemistry teachers of school A administered the test as a model examination to their students. And chemistry teachers of school B administered the test to be part of the final examination that went into students’ academic record. Therefore, students at both schools had taken the test being in the exam mood.

Procedures of the open-ended and semi- questionnaire administration

In both schools the questionnaire was administered to the students in the department of chemistry. The seat arrangements were U-shape. My seat was directly in front of the U-shape so that it was very comfortable for giving explanation to each question and when the need arose for further clarification to any of the questions. After the seat arrangement had been made, I handed out the questionnaire to each of the participants. Then, I gave them oral description turn by turn to each question before they started to fill it in. The social setting was made friendly as much as possible to the participants. Moreover, pen and refreshments were provided to them.

Ethical consideration*s*

In this study ethical issues were taken seriously. The participation of students, school principals, school communities (such as teachers and academic record staffs, and librarians), and educational officers of the district in the project was based on their full consent. They expressed their consent through the legal framework of the school systems (see Appendix F).

In the current Ethiopian education system, preparatory schools function under the protectorate of North Shoa Educational Department in Amhara National State Education Bureau. Therefore, the researcher first requested and secured a cooperation letter written by UNISA Regional Learning Center from UNISA Ethiopia Regional office (see Appendix F). Then, prior to stepping into the schools, the researcher handed the cooperation and application letters to Curriculum Design and Implementation core process office of North Shoa Educational Department in Amhara National State Education Bureau to ask permission to conduct the research in the schools. The bureau appreciated and positively responded to the request and wrote letters that state each school to collaborate with me during the research work (see Appendix F). The letters were given to the respective school directors. Each of the school Directors directed the letter to deputy Directors, and then to chemistry department, and finally to Ethiopian Teachers' association representatives of the schools. Chemistry department head of each school introduced me with chemistry teachers in the school. Then, chemistry teachers in both schools welcomed me warmly and introduced to their students. I briefly described the purpose and expected benefits of the research to students and teachers. After the briefings, students were very much interested to know about their learning styles preferences and to take tests which could prepare them for national examinations. Finally, it was agreed that information collected during the research process to be kept confidential or not to be used for any other purposes. The researcher assured students that no part of their identity including names be presented in the results of the study. The participants' names are kept confidential and represented by codes. The data collection schedule was set based on negotiation and not to clash with the regular programme. On top of this, all references cited in this work are acknowledged. If there should be any instances where references cited in this work was not acknowledged, I declare that absolutely it was not intentional.

4.4 Data analysis techniques

A mixed-methods sequential explanatory design involves collecting and analyzing first quantitative and then qualitative data in two consecutive phases within one study (Ivankova, Creswell, & Stick, 2006b). In this study, the quantitative data and their subsequent analysis were used to provide a general understanding of how learning styles and which learning styles better predicted academic performance on some fundamental concepts in chemistry. However, the qualitative data collection and analysis were employed to provide detailed descriptions on how chemistry instructional materials used by the school explain academic performance of students with the same learning styles or students with different learning styles. Ivankova and et al. (2006b) stated that qualitative data and their analysis can refine and explain statistical results by exploring participants' views in more depth and more useful ways, especially when unexpected result arises from the quantitative data.

Quantitative data analysis

In this phase, multiple regression analysis was employed to determine how Felder-Silverman's learning styles independently and in combination correlate with and/or predict student's academic performance on some fundamental concepts in chemistry. Multiple regression is a statistical technique used to determine a correlation between a criterion variable and the best combination of two or more predictor variables (Fraenkel & Wallen, 2005). Moreover, an independent sample t-test was employed to test if there was statistically significant difference in academic performance on some fundamental concepts between visual and verbal, or sensing and intuitive, or active and reflective, or sequential and global learners.

Qualitative data Analysis

A framework analysis approach was applied to analyze my qualitative data. According to J. Green and Thorogood (2004), a framework analysis involves thematic analysis and then comparisons both within (between themes) and between cases. Thus, students' responses to the semi-structured questionnaire and open-ended questionnaire was coded and organized around the questions. Subsequently, a comparative analysis was made in two dimensions: A case wise and variable wise analysis. The case wise analysis was done on the data by comparing the responses of extremely high performing students, extremely low performing students and students with the same learning styles. The variable wise analysis was made by comparing participants' response on different variables or questions. Finally, conclusions were drawn about the effect of instructional materials on students’ academic performance on some fundamental chemical concepts under investigation.

Chapter-5

Result of quantitative phase of the study

Introduction

In this phase of the study, empirical data were collected and analyzed to answer two research questions. The research questions were:

Question 1: How well do learning styles predict academic performance in chemistry among preparatory school natural science students? In other words, how much variance in academic performance in chemistry can be explained by the variation in learning styles?

Question 2: Which learning style best enhances students' academic performance in chemistry: a) Visual or Verbal; b) Sensing or Intuitive; c) Active or Reflective; d) Sequential or Global learning styles?

The aim of the first research question was to determine the proportion of measures of variations in academic performance on some fundamental chemical concepts in the topics: atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms from Felder-Silverman learning styles. And the aim of the second research question was to test if there were statistically significant difference in measures of academic performance on some fundamental concepts in the topics: atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms between a) Visual and Verbal learners, b) Sensing and Intuitive learners, c) Active and

Reflective learners, and d) Sequential and Global learners. In order to answer these two research questions in the quantitative phase of the study, data were collected through the Index of Learning styles (ILS) and chemistry test. The data was analyzed using descriptive and inferential statistics.

The analysis to answer the first research question (i.e. How well do learning styles predict academic performance in chemistry among preparatory schools natural science students?) was organized in to five sections: 1) The distribution of students across Felder-Silverman's learning style dimensions, 2) Students' academic performance on some fundamental concepts in chemistry versus Felder-Silverman learning styles , 3) Extreme academic performance by some science students with the same learning style combinations, 4) Correlations between dependent and predictor variables and among each other, and 5) Predicting academic performance on some fundamental concepts in chemistry from Felder-Silverman learning styles: Multiple regression analysis.

In order to answer the second research question, comparison of students' academic performance was conducted using an independent sample t-test and correlational coefficients. The analysis was organized and entitled as comparing students' academic performance on some fundamental concepts in chemistry against their Felder-Silverman learning styles.

5.1 The distribution of students across Felder-Silverman's learning style dimensions

In this section, the distribution of students across: receptive style (Visual/Verbal and Sensing/Intuitive), and information processing learning styles (Active/Reflective & Sequential/Global) are analysed. A total number of 326 students participated in this study. All completed the Index of learning style questionnaire and sat for the test administered to measure their academic performance on some fundamental concepts in chemistry. The distribution of participants by learning styles dimensions are summarized in the frequency table below (Table 5.1).

Table 5.1 Grade 11 and 12 science students' Felder-Silverman's learning styles

The dimensions of Felder-Silverman's learning styles	Students' distribution in each learning style dimension by grade level				Total	
	Grade 11		Grade 12			
	Number (n)	Percent (%)	Number (n)	Percent (%)	(n)	%
Sensing	127	76.05	132	83.02	259	79.44
Intuitive	40	23.95	27	16.98	67	20.56
Total	167	100	159	100	326	100
Visual	101	60.48	111	69.81	212	65.03
Verbal	66	39.52	48	30.19	114	34.97
Total	167	100	159	100	326	100
Active	85	50.90	85	53.46	170	52.15
Reflective	82	49.10	74	46.54	156	47.85
Total	167	100	159	100	326	100
Sequential	55	32.93	49	30.82	104	31.90
Global	112	67.07	110	69.18	222	68.10
Total	167	100	159	100	326	100

Table 5.1 shows that the majority of students in both grade 11 (n = 127, 76.05) and grade 12 (n = 132, 83.02%) were Sensing learners. In general from the total number of participant students (n = 326) in both grade levels, 79.44 (n = 259) percent of them were identified as Sensing

learners (n = 259) whereas the remaining 20.56 (n = 67) percent of science students were Intuitive learners.

On the topic of the Visual and Verbal learners, Table 5.1 shows that the majority of science students in both grade 11(n=101 out of 167 representing 60.48%) and grade 12 (n=111 out of 159 representing 69.81%) were Visual learners. This tells us that 65.03 percent (n= 212) of the 326 participants of the study were identified as Visual learners. The remaining 34.97 percent (n = 114) of science students were identified in the Verbal learning style dimension.

Similarly when comparing the size of Active and Reflective learners, Table 5.1, reveals that 50.90 percent (n = 85) of grade 11 science students were Active learners and the remaining 49.10 percent (n = 82) of students were Reflective learners. Similarly, 53.46 percent (n = 85) of grade 12 students were identified as Active learners and the remaining 46.54 percent (n = 74) of students were Reflective learners. Therefore, out of 326 students, 52.15 percent of students (n = 170) were Active learners and the remaining 47.85 percent (n = 156) were Reflective learners. The data shows that, although the majority of science students in both grade levels were Active learners, the disparity of distribution between Active and Reflective learners was not as high as the disparity of students' distributions observed between Sensing and Intuitive learners, and the disparity of distributions observed between Visual and Verbal learners.

Concerning students' learning styles on the Sequential/Global dimensions of Felder-Silverman model, the majority of students found Global learners. Table 5.1 shows that, out of 167 grade 11 students, 32.93 percent (n = 55) of the students were identified as Sequential learners and the remaining 67.07 percent (n = 12) were Global learners. Similarly, 30.82 percent of grade 12 students (n = 49) were Sequential learners whereas the remaining 69.18 percent (110) of the students were Global learners. Thus in both grade levels the majority of the students, i.e. 68.1

percent (n = 222) were Global learners and the remaining 31.90 percent (n = 104) of 326 students were sequential learners.

The study revealed that the majority of the students were Visual (65.03%), Sensing (79.44%), Active (52.15) and Global (68.10) learners. Except for distribution of Sequential/Global learning style dimensions, the distribution of learning styles observed in this study was very consistent with other research reports. For instance the study conducted in the University of Sydney showed that the majority of first year chemistry students were Sensing learners (Yeung, et al., 2006). A similar study also showed that the overall learning styles profile patterns of science, technology, engineering and mathematics students were Visual, Active, Sensual and Sequential (Harvey, et al., 2010; Palou, 2006a). However, this study revealed that the majority of the students were global learners. Therefore, in scenarios when it is difficult to address all learning preferences, the teaching-learning process and designing chemistry instructional materials has to give more attentions the majority (i.e. Global learners).

5.2 Students' academic performance on some fundamental concepts in chemistry versus Felder-Silverman learning styles

In this section, both grade 11 and grade 12 students' academic performance scores on some fundamental concepts in chemistry against their Felder-Silverman learning style was presented in Tables 5.2 and 5.3. Their academic performance scores within each dimensions of learning styles is statistically described using means, standard deviations, and estimated region for the location of the true mean at 95 percent confidence interval. Moreover, some unique observations of cases, namely: students with the same learning style combinations but who had extremely different academic performance scores on some fundamental concepts in chemistry were presented in Table 5.4.

Samples from grade 11 natural science students took the same test constructed from some fundamental concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure in grade 11 students' chemistry text book. Therefore, their academic performance scores on the test against their Felder-Silverman learning styles dimensions are summarized and presented in Table 5.2.

Table 5. 2. Grade 11 science students' performance on some fundamental concepts in chemistry against their learning styles

Learning style dimensions	Number of students (n)	Performance means for each learning style dimension			St. deviation and Variance		Skewness
		95% Confidence Interval for Mean		Mean	Std. Deviation	Variance	
		Lower bound	Upper bound				
Sensing	127	11.37	12.43	11.90	3.01	9.06	-.048
Intuitive	40	10.72	12.73	11.73	3.15	9.95	-.024
Visual	101	11.12	12.33	11.72	3.05	9.32	-.026
Verbal	66	11.32	12.80	12.06	3.02	9.14	-.039
Active	85	11.25	12.51	11.88	2.92	8.53	-.019
Reflective	82	11.13	12.53	11.83	3.17	10.05	-.040
Sequential	55	10.66	12.32	11.49	3.09	9.48	.205
Global	112	11.47	12.60	12.04	3.01	9.08	-.148

In the same way, samples from grade 12 science student took the same test constructed from some fundamental concepts in the topics: Acid-base equilibrium and common thermodynamic terms in grade 12 students' chemistry text book. And their academic performance scores on the test is organized based on their learning style dimensions and then presented in Table 5.3.

Table 5.3 Grade 12 science students' performance on some fundamental concepts in chemistry against their learning styles

Learning style dimensions	Number of students (n)	Performance means for each learning style dimension			St. deviation and Variance		Skewness
		95% Confidence Interval for Mean					
		Lower bound	Upper bound	Mean	Std. Deviation	Variance	
Sensing	132	12.20	13.41	12.80	3.50	12.25	.052
Intuitive	27	10.78	14.04	12.41	4.12	16.94	-.415
Visual	111	12.35	13.76	13.05	3.73	13.89	-.069
Verbal	48	11.07	12.93	12.00	3.21	10.30	-.343
Active	85	11.83	13.35	12.59	3.54	12.51	.128
Reflective	74	12.05	13.76	12.91	3.69	13.62	-.027
Sequential	49	11.75	13.92	12.84	3.78	14.26	-.221
Global	110	12.02	13.36	12.69	3.54	12.51	.001

Table 5.2 shows that, the mean for academic performance scores of grade 11 *S*ensing learners and *I*ntuitive learners were 11.90 and 11.73 respectively. The Table also shows that at 95 percent confidence interval, the lower and upper bound for the true mean of academic performance was 11.37 and 12.43 for Sensing learners, and 10.72 and 12.73 for Intuitive learners. This suggests that the probability of finding the location of the true score at 95 percent

confidence interval for both Visual and Verbal learners was within a similar region of distribution of their academic performance scores. Furthermore, the table shows that the measure of standard deviation for the spread of academic performance scores for Sensing learners was 3.01 and for Intuitive learners was 3.15. This measure of standard deviation indicates that the distribution of scores was nearly the same for both Sensing and Intuitive learners.

Concerning Sensing and Intuitive learners of grade 12 science students, Table 5.3 shows that the mean for academic performance scores of Sensing learners was 12.80 and Intuitive learner was 12.41. At 95 percent of confidence interval, the lower and the upper bound of the true mean of measures of academic performance score was 12.20 and 13.41 for Sensing learners, and 10.78 and 14.04 for Intuitive learners. Obviously, the interval for the probability of finding the true mean was slightly wider for Intuitive learners than Sensing learners, but these regions of finding the true means of academic performance scores of Sensing and Intuitive learners was comparable. And the measure of standard deviation for the distribution of academic performance scores was 3.50 for Sensing learners and 4.12 for Intuitive learners. This further suggests that the distribution of academic performance scores of Intuitive learners was relatively more scattered than academic performance scores of Sensing learners. But difference was small to consider.

In sum in both grade 11 and 12, small difference was observed between the means, the location of the true means at 95% confidence intervals and the measures of dispersions of Sensing and Intuitive learners' academic performance scores. Hence, from the sample data it can be concluded that being Sensing or Intuitive learner has little contribution to students' academic performance on some fundamental concepts in chemistry at both grade levels.

The other dimension of Felder-Silverman learning styles is a Visual/Verbal learning style dimension. The data on grade 11 Visual and Verbal learners' academic performance scores on the test constructed from some fundamental concepts in chemistry is presented in Table 5.2. As it can be observed in the table, the mean of academic performance scores was 11.72 for Visual learners and 12.06 for Verbal learners. Table 5.2 also shows that at 95 percent confidence interval, the lower and upper bound for the true mean of academic performance scores of Visual learners was 11.12 and 12.33 and Verbal learners was 11.32 and 12.80. This means that the probability of finding the location of the true score at 95 percent confidence interval for both Visual and Verbal learners was almost within same region of distribution of scores. Moreover, Table 5.2 shows that the measures of standard deviation about the distribution of academic performance scores was 3.05 for Visual learners and was 3.02 for Verbal learners. This demonstrates that the distribution of academic performance for both Visual and Verbal learners was approximately comparable.

In the same fashion grade 12 Visual/Verbal learners' academic performance scores on the test constructed from some fundamental concepts in chemistry is presented in Table 5.3. The table shows that the mean of Visual learners' academic performance scores was 13.05, whereas the mean of Verbal learners' academic performance scores was 12.00. This also shows that, at 95 percent confidence interval, the lower and upper bound for the true means of academic performance scores of Visual learners was 12.35 and 13.76 and of Verbal learners was 11.07 and 12.93. This implies that at 95 percent confidence interval, the range for the probability of finding the true mean of Visual learners' academic performance is slightly shifted to the regions of higher scores compared to the location of the true mean of Verbal learners' academic performance. It also shows that the standard deviation for the dispersion of academic performance scores was 3.73 for Visual learners and was 3.21 for Verbal learners. It means that the distribution of academic performance scores for both Visual and Verbal learners were similar.

In general, the statistics of both grade 11 and 12 Visual and Verbal learners' academic performance scores on some fundamental concepts in chemistry found slightly different. It means that the difference in their academic performance was small. Therefore, from the sample means and standard deviations presented in Table 5.2 and Table 5.3, the researcher has learned that the difference between Visual or Verbal students' academic performance on some fundamental concepts in chemistry was small. This tends to imply that a variation in Visual/Verbal learning style is linked to variations in academic performance on some fundamental concepts in chemistry is not large.

Students' academic performance on some fundamental concepts in chemistry against their Active/Reflective dimensions of learning styles were also considered in the study. The observations of grade 11 students' academic performance scores on some fundamental concepts in chemistry are presented in Table 5.2. As it can be seen from the fourth row of Table 5.2, the mean of academic performance scores of Active learners was 11.88 and the mean of academic performance scores of Reflective learners was 11.83. It also shows that at 95 percent confidence interval, the lower and upper bound for the true mean of academic performance scores of Active learners was 11.25 and 12.51, and of Reflective learners was 11.13 and 12.53. This means that the probability of finding the locations of the true means at 95 percent confidence interval for both Active and Reflective learners were still approximately within the same region of distribution of the scores. Regarding the dispersion of their academic performance scores about the mean, the table shows that measures of standard deviation of academic performance scores was 2.92 for Active learners and 3.17 for Reflective learners. This suggests that there was a slight difference in the distribution of scores for both Active and Reflective learners.

Likewise, the academic performance scores on some fundamental concepts in chemistry of grade 12 Active and Reflective learner was presented in Table 5.3. As it can be read from Table 5.3, the mean of academic performance scores of Active learners was 12.59 and the mean of academic performance scores of Reflective learners was 12.91. The Table also presents that, at 95 percent confidence interval, the lower and upper bound of the true means of academic performance of Active learners is 11.83 and 13.35, and of Reflective learners is 12.05 and 13.76. This indicates that the interval for the probability of finding the true mean of both Active and Reflective learners was approximately within similar range of distribution of scores. The measure of standard deviation for the distributions of scores of Active learners' academic performance of is 3.54 and of Reflective learners' academic performance is 3.69. This suggests that the spread of Active and Reflective learners' academic performance scores was similar.

As a whole, the mean, the location of the true mean at 95 percent confidence interval and standard deviations of grade 11 and 12 natural science students' academic performance scores fails to reveal a noticeable variation in academic performance on some fundamental concepts in chemistry which is linked to Active or Reflective learning styles. Hence, this sample statistics implies that being Active or Reflective learners couldn't result in noticeable difference in students' academic performance on some fundamental concepts in chemistry among grade 11 and 12 science students.

Finally grade 11 and 12 science students' academic performance scores on some fundamental concepts in chemistry against their Sequential/ Global learning style dimensions are examined. The Sequential and Global learners of grade 11 natural students' academic performance scores on some fundamental concepts in chemistry was presented in Table 5.2. As it can be observed in Table 5.2 the mean for academic performance scores of Sequential learners was 11.49 and of Global learners was 12.04. The Table also shows that the lower and upper bound of the true mean of academic performance scores at 95 percent confidence interval was 10.66 and 12.32 for Sequential learners, and was 11.47 and 12.60 for Global learners. This tells us that at 95 percent confidence interval, the true means of academic performance scores of Visual and Verbal learners was located within similar region of distribution of their academic performance scores. What is more in Table 5.2 is that, the measure of standard deviation for the distribution of academic performance scores was 3.09 for Sequential learners and was 3.01 for Global learner. This implies that the spread of both Sequential and Global learners' academic performance scores around their respective means was similar.

Sequential and Global learners' academic performances on some fundamental concepts in chemistry among grade 12 natural science students were also measured and presented in Table 5.3. As can be noticed in Table 5.3, the mean of academic performance scores of Sequential learners was 12.84 and the mean of academic performance scores of Global learners was 12.69. Table 5.3 also presents that, at 95 percent of confidence interval, the lower and upper bound for the true mean of academic performance scores was 11.75 and 13.92 for Sequential learners, and 12.02 and 13.36 for Global learners. And the measure of standard deviation for the distribution of academic performance scores of Sequential learners was 3.78 and of Global learners was 3.54.

This implies that the spread of academic performances around their respective means was approximately the same.

The comparisons of means of Sequential learners' and Global learners' academic performance scores on some fundamental concepts in chemistry presented in Table 5.2, and Table 5.3 reveals little difference. This means that the link between academic performance differences on some fundamental concepts in chemistry and Sequential or Global learning styles of grade 11 and 12 science students were small.

As a whole the descriptive statistics for the measures of academic performance of both grade 11 and 12 students on the fundamental chemical concepts considered in this study showed that, there was little noticeable performance difference associated with learning styles differences. In other words, statistical differences observed on the measures of academic performances between Visual and Verbal, or Sensing and Intuitive, or Active and Reflective, or Sequential and Global learner was very small. This means that, the means, standard deviations, and the location of the true mean at 95% confidence level for measures of academic performance were nearly similar for Visual and Verbal, Sensing and Intuitive, Active and Reflective, and Sequential and Global learners.

Thus, to check if these small mean differences in students' academic performance on some fundamental concepts in chemistry are statistically significant or not, the data is further subjected to significant tests. Moreover, the learning styles and academic performance of some extreme (deviant) cases are further analyzed in the following section entitled as "Extreme academic performance by some science students with the same learning style combinations".

5.3 Extreme academic performance by some science students with the same learning style combinations

To further substantiate how academic performance is linked to learning styles, some extreme cases (i.e. students with extremely different academic performance) which have the same or different learning style combinations were selected and presented in Table 5.4. Here, extreme case stands for students with extremely different academic performance on the tests constructed from some fundamental concepts in chemistry.

In this study there were some students who had the same learning style combinations but with extremely different academic performance (i.e. extremely high or extremely low performance) on some fundamental concepts in chemistry. Moreover, there were some students who had different learning style combinations and who had extremely low or extremely high academic performance on some fundamental concepts in chemistry. These extreme cases are identified using Boxplot and the statistical distribution of extreme test scores. Some of them are summarized in Table 5.4 and selected to be included as participants of the qualitative part of this study.

Table 5.4 Grade 11 and 12 Students' with the same learning style and extremely different academic performance on the tests

No	Sample learning style combinations	Number of students Performed extremely high (who scores ≥ 21 out of 22)	Number of students Performed extremely low (who scores ≤ 5 out of 22)
1	Visual + Sensing +Reflective + Global	2	1
2	Visual + Sensing +Reflective +Sequential	1	1
3	Visual + Sensing +Active + Global	2	1
4	Visual + Intuitive +Reflective + Global	1	1
5	Visual + Sensing +Active + Sequential	1	1
	Total	7	5

As it can be seen from Table 5.4 (i.e. in rows one through five), despite the fact that students had the same learning style combinations, their academic performance was extremely different on some fundamental concepts in chemistry. The extreme cases presented in Table 5.4 show that, out of students having the same learning style combinations some of them performed extremely different. For example in row 1, out of three students having the same learning style combinations two of them performed extremely high but the other extremely low, the same holds true in the third row. Moreover, as it can be seen in each of rows 2, 4, and 5, there were two students who have the same learning styles: one performed extremely high and the other performed extremely low. This implies that having the same learning styles combinations couldn't put students on a similar status of academic performance on some fundamental concepts in chemistry.

However, the researcher's expectation was that students with the same learning style combinations to show at least a similar trend of academic performance on the same test constructed from the same fundamental chemical concepts taught under the same instructional context. This expectation was not supported by the empirical data presented in Table 5.4. This result inspired me to further study if there might be a possibility of other important variables which contribute more to academic performance on some fundamental concepts in chemistry than learning styles can do. Therefore, I included these extreme cases to be participants for the qualitative part of the study.

5.4 Correlations between dependent and predictor variables and among each other

The correlation coefficients and significance tests were computed for the data to observe the degree of association between the dependent (academic performance) and the predictor variables (Felder-Silverman learning styles). The statistics that show the correlation coefficients and significance tests that measure the correlation between Felder-Silverman learning styles and academic performance among grade 12 natural science students is summarized and presented in Table 5.5.

Table 5.5 Correlations between academic performance and Felder-Silverman learning styles and among each other for grade 12 science students

		Performance	Sensing /Intuitive	Visual/Verbal	Active/ Reflective	Sequential/ Global
Pearson Correlation	Performance	1.000				
	Sensing/Intuitive	.041	1.000			
	Visual/Verbal	.135	-.078	1.000		
	Active/Reflective	-.044	.048	-.009	1.000	
	Sequential/Global	.019	.048	-.095	-.005	1.000
Sig. (1-tailed)	Performance	.				
	Sensing/Intuitive	.302	.			
	Visual/Verbal	.045	.163	.		
	Active/Reflective	.291	.273	.454	.	.
	Sequential/Global	.407	.274	.116	.473	.
N	Performance	159	159	159	159	159
	Sensing/Intuitive	159	159	159	159	159
	Visual/Verbal	159	159	159	159	159
	Active/Reflective	159	159	159	159	159
	Sequential/Global	159	159	159	159	159

As it can be seen from the table, the correlation coefficients between Sensing/Intuitive and performance (r_1 = -.041, p= .302); Active/Reflective and performance (r_3 = -.044, p= .291) and, Sequential/Global and performance (r_4= .019, p=.407) were below 0.3. Moreover, the table presents that at $\alpha = 0.05$, none of the predictor variables but Visual/Verbal was statistically significantly related to academic performance on some fundamental concepts in chemistry. However, there was statistically significant relationship between Visual/Verbal and academic performance at $\alpha = 0.05$ ($r_2 = .135$, $p=.045$). Table 5.5 also shows that none of the relationships among predictors was greater than .25.

Similarly, the statistics that show the correlation coefficients and significance tests that measures the correlation between Felder-Silverman learning styles and academic performance among grade 11 natural science students was summarized and presented in Table 5.6.

Table 5.6 Correlations between academic performance and Felder-Silverman learning styles and among each other for grade 11 science students

		Performance	Sensing/ Intuitive	Visual/Verbal	Active/Reflective	Sequential/ Global
Pearson Correlation	Performance	1.000				
	Sensing/Intuitive	.024	1.000			
	Visual/Verbal	-.055	-.109	1.000		
	Active/Reflective	.009	.038	.162	1.000	
	Sequential/Global	-.085	.125	-.033	.077	1.000
Sig. (1-tailed)	Performance	.	.377	.242	.455	.139
	Sensing/Intuitive	.377	.	.080	.312	.054
	Visual/Verbal	.242	.080	.	.019	.336
	Active/Reflective	.455	.312	.019	.	.163
	Sequential/Global	.139	.054	.336	.163	.
N	Performance	167	167	167	167	167
	Sensing/Intuitive	167	167	167	167	167
	Visual/Verbal	167	167	167	167	167
	Active/Reflective	167	167	167	167	167
	Sequential/Global	167	167	167	167	167

As it can be seen from Table 5.6, the correlation coefficients for the relation between Sensing/Intuitive and performance (r_1 = 024, p= .377); Visual/Verbal and performance (r_2 = -.055, p=.242), Active/Reflective and performance (r_3 = -.009, p= .455) and, Sequential/Global and performance (r_4= -.085, p=139) was below 0.3. Moreover, at α = 0.05, none of the predictor variables were statistically significantly related to academic performance on some fundamental concepts in chemistry. The table also shows that, none of the relationships among the predictors was greater than .25. This shows that low relationships were observed among the predictor variables in the Correlations table. This is good, because this implies that the multicollinearity problem among the predictor variables was low.

In sum, the means, confidence intervals, standard deviations and measures of correlation in the current study showed that there was very small systematic variation in academic performance on some fundamental concepts in chemistry associated with variations in learning style. Thus, multiple regression analysis was conducted to determine or predict the amount of variation in academic performance on some fundamental concepts in chemistry from Felder-Silverman's learning styles.

5.5 Predicting academic performance on some fundamental concepts in chemistry from Felder-Silverman learning styles: Multiple regression analysis

The first research question of this study was: How well do learning styles predict academic performance in chemistry among preparatory school natural science students? The quantitative data of the current study was subjected to the Regression model fit test which has one dependent and four predictor variables. Therefore, the indices of the coefficient of determination (R square) in Tables 5.9 and 5.11, and ANOVA tests for R^2 of the regression model in Tables 5.10 and 5.12 were used to empirically answer this research question.

The regression model equation is presented as follows:

$$\text{Academic Performance} = \beta_0 + \beta_1 \text{ (Visual/Verbal)} + \beta_2 \text{ (Sensing/Intuitive)} + \beta_3 \text{ (Active + Reflective)} + \beta_4 \text{ (Sequential/Global)} + \epsilon, \text{ where}$$

β_0 is the intercept-the mean of the academic performance when learning style dimension has no effect on academic performance, while β_1, β_2, β_3, and β_4 are standard coefficients of the predictor variables (learning style dimensions), and ϵ stands for an error term in the model. Accurate estimate of standard coefficients β_1, β_2, β_3, and β_4 of the regression model indicates the relative importance of each dimension of learning styles in explaining academic performance on some fundamental concepts in chemistry. Before the application of multiple regression analysis (testing the regression model), the assumptions of multiple regressions, such as multicollinearity, homoscedasticity or normality of residuals and linearity were checked on the data.

Test for the assumptions of multicollinearity among the predictor variables

According to Chatterjee and Hadi (2006), if there is multicollinearity problem among the predictor variables, the regression equation is very unstable from one sample of data to the other which in turn can lead to erroneous inferences. According to Gaur and Gaur (2009, p. 109), "multicollinearity causes inflation to standard errors of the regression coefficients that lead to the reduction of their significance". Therefore, an assumption of multicollinearity was checked via its indicators, such as tolerance and the variance inflation factor (VIF) using SPSS package.

If tolerance is below 0.1 and VIF (the reciprocal of tolerance) is greater than 10%, it indicates a multicollinearity problem (Chatterjee & Hadi, 2006; Ho, 2006; Mooi & Sarstedt, 2011). Gaur and Gaur (2009) specifically put a rule of thumb that for natural sciences, problem of multicollinearity exists if tolerance is 0.2 and VIF values is greater than 5, however for social sciences a VIF of 10 is acceptable. According to Chatterjee and Hadi (2006), VIF value greater than 10 signals a problem of multicollinearity but a value close to 1 signals orthogonality among the predictor variables. Therefore, in view of afore stated academics the tolerance and VIF values were examined for both grade 12 and 11 students (see Table 5.7 and Table 5.8).

Table 5.7 Collinearity statistics for grade 12 science students

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta (β)			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	11.65	.916		12.72	.000	9.84	13.45		
	Sensing/Intuitive	.509	.765	.053	.665	.507	-1.002	2.020	.990	1.01
	Visual/Verbal	1.11	.627	.141	1.76	.080	-.134	2.344	.985	1.01
	Active/Reflective	-.325	.574	-.045	-.567	.572	-1.458	.808	.998	1.00
	Sequential/Global	.229	.622	.029	.368	.714	-1.001	1.458	.989	1.01

As it can be read from Table 5.7, the collinearity statistics of Tolerance on Sensing/Intuitive dimension (.990), Visual/Verbal Dimension (.985), Active/Reflective Dimension (.989), and Sequential/Global Dimension (.989) was well greater than 0.1. Moreover, according to Leech, Barrett, and Morgan (2005) if tolerance values is less than 1-R^2 (where R^2 is adjusted R^2 of the regression model*)* (i.e. $< 1-R^2$), there may be a probability for the existence of multicollinearity problem. However, in this study the adjusted R^2 was -.002, and $1-R^2$ was 1.002 well above the least tolerance value which is .985. Therefore, there was no sign of probability for multicollinearity problem among the predictor variables.

Table 5.8 Collinearity statistics for grade 11 science students

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta (β)			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	12.042	.625		19.280	.000	10.808	13.275		
	Sensing/Intuitive	.202	.562	.028	.359	.720	-.908	1.312	.971	1.030
	Visual/Verbal	-.361	.494	-.058	-.732	.465	-1.336	.613	.960	1.042
	Active/Reflective	.146	.481	.024	.304	.762	-.804	1.097	.965	1.036
	Sequential/Global	-.592	.509	-.092	-1.164	.246	-1.596	.412	.978	1.022

a. Dependent Variable: Performance

Table 5.8 shows that the Tolerance of Sensing/Intuitive (.971), Visual/Verbal Dimension (.960), Active/Reflective Dimension (.965), and Sequential/Global Dimension (.978) was not below 0.1. Moreover, the adjusted R^2 was -.013. And $1-R^2$ was 1.013 well above the least tolerance value which was .960. This implies that there was no sign of probability for multicollinearity problems among the predictor variables (the learning styles).

In conclusion, the multicollinearity test on the predictor variables showed that there was not a sign of multicollinearity problem among the predictor variables. The tolerance and VIF values for all the four learning style dimensions in Table 5.7 and 5.8 prove that, there was no sign of multicollinearity problem.

Test for assumptions of linearity between the dependent variable and predictors

The scatter plot of the data points on academic performance in some fundamental concepts in chemistry of grade 12 students against their learning style dimensions showed that the assumption of linearity was not violated for the predictor (learning styles) and criterion variables (performance), (See Figure 5.1).

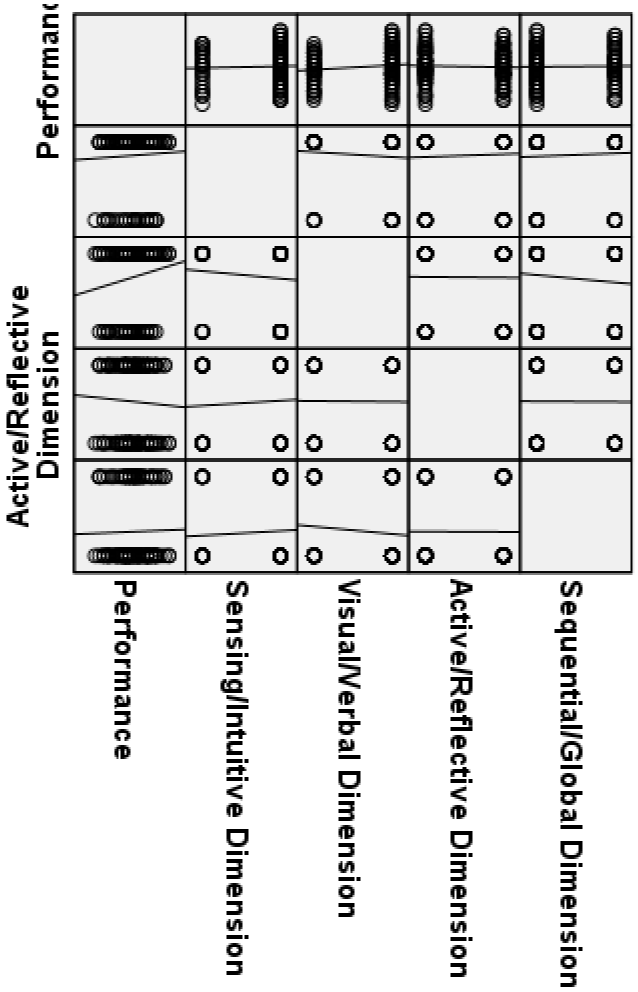


Figure 5.1: Scatter plot of the dependent variable with four predictor variables for grade 12 students

As it can be seen from Figure 5.1, the top row shows the plots of relationship between academic performance (dependent variable) and the four dimensions of learning styles (predictor variables). It is because, according to Leech, et al. (2005, p. 99) "Dichotomous variables have two column (or rows) of data points" and the linearity assumption of regression analysis would be violated if the data points of the dichotomous variables are gathering/group "at the center of one column and at the ends of the other column". They further explains that "If the data points bunch up near the top of left column and the bottom of the right, the correlation will be negative (and vice versa)" (Leech, et al., 2005, p. 99). Hence, in the above figure the scatter plot of dependent variable with the predictors revealed that the data points of the dichotomous variables within each of the second, third, fourth and fifth column of the top row were not gathered at the center of one column and at the end of the other column. Therefore, the assumption of linearity was not violated.

Similarly, the scatter plots of the data points on academic performance of grade 11 science students against their learning style dimensions showed that the assumption of linearity was not violated for the relationship between the predictor and criterion variable.

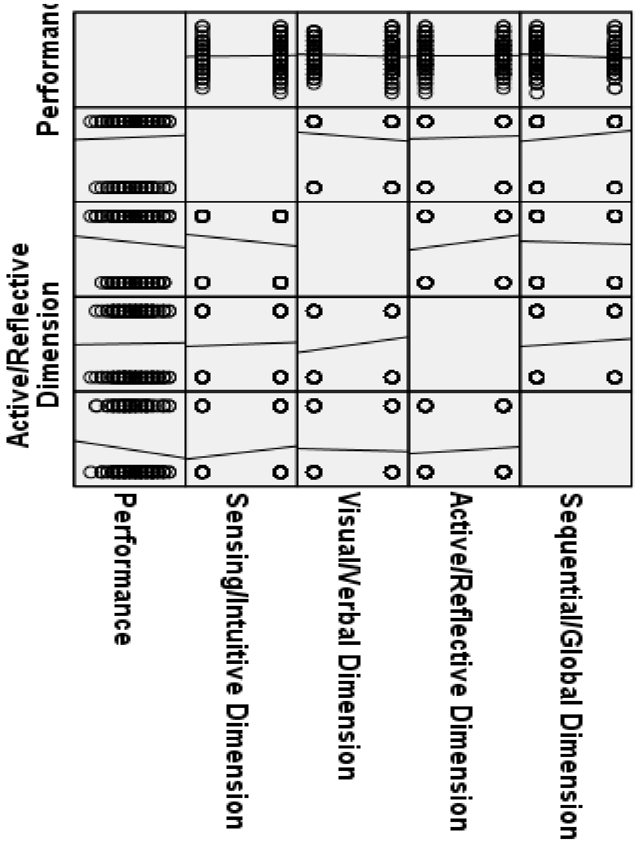


Figure: 5.2. Scatter plot of the dependent variable with four predictor variables for grade 11 students

As it can be seen from Figure 5.2, the top row shows that the relationship plots of the academic performance (dependent variable) and the four dimensions of learning styles (predictor variables). In the above figure, the scatter plots of dependent variable with the predictors revealed that, the data points of the dichotomous variables within each of the second, third, fourth and fifth column of the top row were not gathered at the center of one column and at the end of the other column. Therefore, the assumption of linearity was not violated.

In conclusion, the scatter plot matrix of data points for both grade 11 and 12 science students shows that each dimensions of learning styles were generally linearly related to the dependent variable of academic performance on some fundamental concepts in chemistry, meeting the assumptions of linearity.

Test for the assumptions of normality of residuals (Constant variance)

According to Leech, et al.(2005, p. 28), to check the normality of the data, "A simpler guideline is that if the skewness is less than plus or minus one (< +/-1.0), the variable is at least approximately normal". Therefore, the skewness test in the last column in Table 5.2 for grade 11 students and Table 5.3 for grade 12 students show that, the values of skewness for academic performance in each learning styles was well less than the absolute value of 1. This indicates that the data on the dependent variable (academic performance) was approximately normally distributed.

Moreover , Cohen, Cohen, West, & Aiken (2003) stated that if the assumptions of normality are violated, the significance tests are invalid, and the residuals are randomly distributed if the residuals of the data are normally distributed. Therefore, the assumption of normality was checked by observing the normal probability plot of residuals.

According to Leech, et al.(2005), in the graphic display of scatter plot, "if the dots created a pattern, this would indicate the residuals are not normally distributed, the residual is correlated with the independent variables, and/or the variances of the residuals are not constant," p.102. Moreover, Freund, Wilson, & Sa (2006) stated that residuals scatter plot of data points that do not violate assumptions of regression model is characterized by randomly the same distribution of points around the horizontal band or intercept ($R^2 = 0$). Freund, et al.(2006) further stated that, however, if the plots of residuals show up a recognizable systematic pattern or a funnel shape that faces towards the left (i.e. the occurrence of larger residuals with larger predicted values) it indicates the violations of assumptions of variations of common variance. In the light of this view, the scatter plot of standard residuals against predicted values of academic performance of both grade 12 and 11 students was examined in Figures 5.3 and 5.4 respectively.

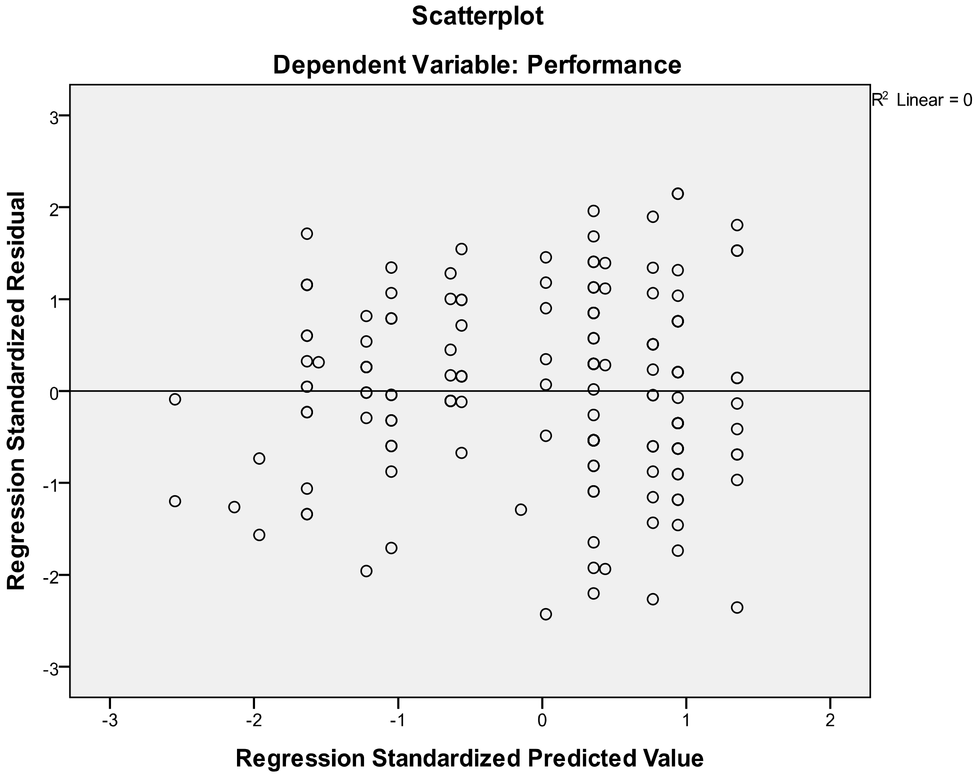


Figure 5.3 Scatter plots of standardized residuals against the fitted (predicted) value of academic performance for grade 12 students

However, as it can be seen from Figure 5.3 the dots were randomly scattered above and below the reference line at $R^2 = 0$ (i.e. they were not scattered systematically), it indicates that the data meet the assumptions of the errors being normally distributed and the variances of the residuals being constant (Freund, et al., 2006; Leech, et al., 2005). Freund, et al.(2006) further stated that if the scatter plot of residuals against predicted value shows no pattern, it indicates the normality of residuals and a homogeneous error of variance across the predicted values. Therefore, in light of this view, it can be concluded that the assumptions of normality and homoscedasticity were satisfied for grade 12 science students to conduct regression analysis.

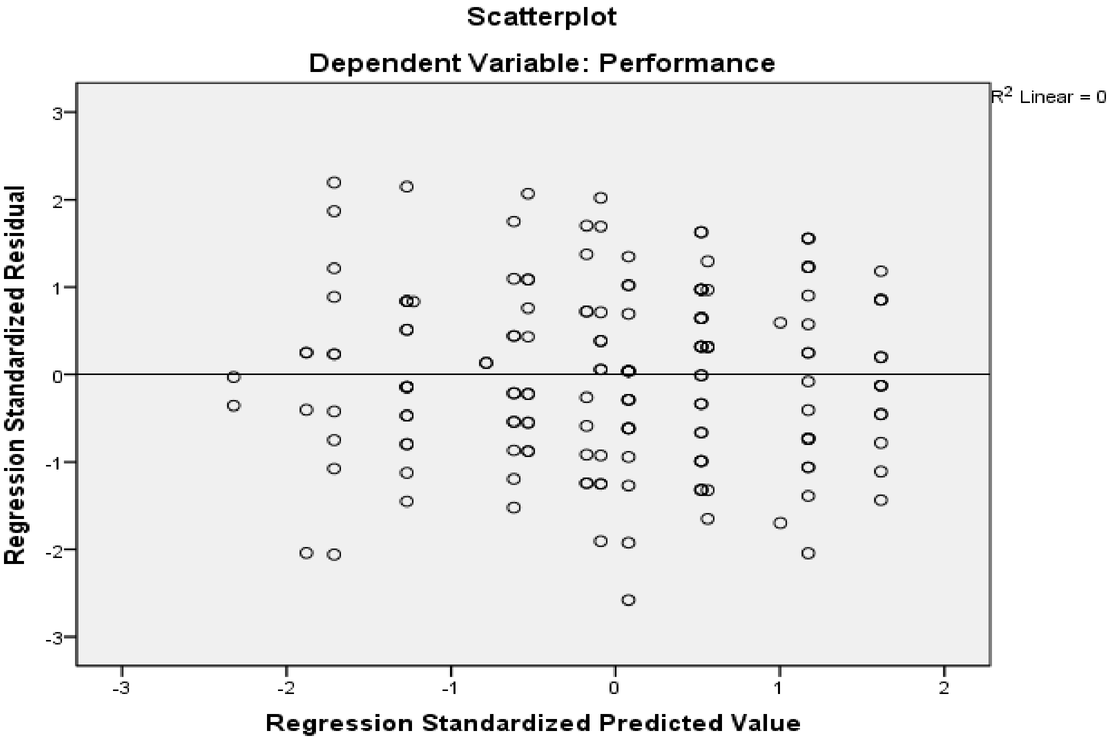


Figure 5.4. Scatter plot of standardized residuals against the fitted (predicted) value of academic performance for grade 11 students

According to Leech, et al. (2005, p. 102) “if the dots created a pattern, this would indicate the residuals are not normally distributed, the residual is correlated with the independent variables, and/or the variances of the residuals are not constant”. However, the dots in Figure 5.4 are scattered and do not show any pattern, therefore it indicates that the data on academic performance of grade 11 science students meet the assumptions of the errors being normally distributed and the variances of the residuals being constant.

In conclusion, the assumptions of normality and homoscedasticity were satisfied for both Grades 12 and 11 science students to conduct a regression analysis. It is because, residual scatter plots of the data for academic performance on some fundamental concepts in chemistry in both Figure 5.3 and 5.4 indicate that the errors were normally distributed, and the variances of the residuals were constant. Moreover, the other major assumptions of multiple regressions were satisfied that supported me to conduct a standard/simultaneous regression analysis on the data.

Regression model fit test by grade level

Once the assumptions of multiple regression was checked and found satisfied, the regression model fit test was conducted on science students' academic performance scores to determine whether the best linear combination of Sensing/Intuitive, Visual/Verbal, Active/Reflective and Sequential/Global can predict students' academic performance on some fundamental concepts in chemistry. The output of regression analysis is presented in Table 5.9 and 5.10; Table 5.11 and 5.12.

Table 5.9 Model Summary : The Regression model fit Test on the data from grade 11 science students

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.109[a]	.012	-.013	3.05545

a. Predictors: (Constant), Sequential/Global , Visual/Verbal , Sensing/Intuitive, Active/Reflective

b. Dependent Variable: Performance

The regression model Summary (Table 5.9) of grade 11 science students' academic performance scores presents the value of R (.109[a]) and R square (.012). It means that 1.2 % variance in academic performance on the tests constructed from some fundamental concepts in chemistry in topics: Atomic structure and periodic table, and chemical bonding and structure in grade 11 chemistry syllabus could be predicted from Felder-Silverman learning styles using the regression model. As it can be seen in this summary model, the adjusted R Square was negative which indicates that the regression model has no intercept. This implies that the model was fairly poor to predict science students' academic performance on some fundamental concepts. Thus, the regression test suggests that the total explanatory power of learning styles in explaining academic performance on some fundamental concepts in chemistry among grade 11 science students was small. This implies that there were other important instructional variables which could explain academic performance than learning styles can do.

The ANOVA part of the regression analysis (see Table 5.10) revealed whether predicting 1.2% variation in academic performance on some fundamental concepts in chemistry from learning styles was statistically significant or not.

Table 5.10 The ANOVA table for significance test of the R^2 of the regression model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.155	4	4.539	.486	.746[a]
	Residual	1512.396	162	9.336		
	Total	1530.551	166			

a. Predictors: (Constant), Sequential/Global Dimension, Visual/Verbal Dimension, Sensing/Intuitive Dimension, Active/Reflective Dimension

As can be seen from the ANOVA (Table 5.10), the model of Sensing/Intuitive, Visual/Verbal, Active/Reflective and Sequential/Global failed to significantly predict academic performance on the test constructed from some fundamental concepts in chemistry, *F* (4, 162) = .486, p=.746[a]. The Coefficients in Table 4.8 also show that all of the predictors did not statistically significantly contributing to the regression model (see the Sig. column). A similar regression model fit test was conducted on grade 12 science students' academic performance scores.

Table 5.11. Model Summary: The Regression model fit Test on data from grade 12 students

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.154[a]	.024	-.002	3.60388

a. Predictors: (Constant), Sequential/Global , Active/Reflective, Sensing/Intuitive , Visual/Verbal

b. Dependent Variable: Performance

The regression model Summary in Table 5.11 gives the R (.154[a]) and R square (.024). The table shows that 2.4% variation in academic performance on some fundamental concepts in chemistry (in the topics: Acid-base equilibrium and common thermodynamic terms) in the regression model was determined from variations in Felder-Silverman's learning styles. This implies that students' learning styles total explanatory power of academic performance was small. Moreover, the adjusted R Square of the model was negative indicating that it was a fairly poor model to predict variance in academic performance on some fundamental concepts from Felder-Silverman learning styles. This further suggests that predicting power of each Felder-Silverman learning styles dimensions was very small (see Table 5.11). This result implies that there were other variables which could explain academic performance than learning styles could do. As it is presented in Table 5.12, the ANOVA part of the regression analysis output shows whether 2.4 % prediction of variance in academic performance from learning styles is statistically significant or not.

Table.5.12 The ANOVA table for significance test of the R^2 of the regression model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.763	4	12.191	.939	.443[a]
	Residual	2000.142	154	12.988		
	Total	2048.906	158			

a. Predictors: (Constant), Sequential/Global Dimension, Active/Reflective Dimension, Sensing/Intuitive Dimension, Visual/Verbal Dimension

b. Dependent Variable: Performance

As can be seen from the ANOVA Table 5.12, the prediction of students' academic performance on some fundamental concepts in chemistry from predictor variables (Sensing/Intuitive, Visual/Verbal, Active/Reflective and Sequential/Global) in the regression model was not statistically significant, F (4,154), p = .443a. The Coefficients in Tables 5.7 also show that all of the predictors did not have a statistically significant contribution to the regression equation (see the Sig. column). In general both the ANOVA Table 5.12 and coefficient Tables 5.7 shows that, the prediction of science students' academic performance on some fundamental concepts in chemistry from learning styles using regression model was not statistically significant. Therefore, this result further gives an insight that the probability of explaining academic performance in chemistry via Felder-Silverman learning styles was not statistically significant at $\alpha = 0.05$, F (4,154), p = 443a.

To put in a nutshell, the outputs of the regression test showed that the prediction of grade 12 science students' (F (4,154), p = 443^a) and grade 11 science students' (F (4, 162) = .486, p=.746a) academic performance on some fundamental concepts in chemistry from the linear combination of learning styles (independent variables) was not statistically significant.

Therefore, the regression model is failed to demonstrate statistically significant prediction of variations in academic performance on some fundamental concepts in chemistry from variations in learning styles. Moreover, the beta weights in Table 5.7 and Table 5.8 shows that being Visual or Verbal, Sensing or Intuitive, Active or Reflective, Sequential or Global learner did not contribute most to predict measures of academic performance on some fundamental chemical concepts considered in this study.

Moreover, the analysis of 12 extreme cases' academic performance (Table 5.4) showed that students with the same learning style combinations performed extremely different (i.e. some extremely high and others performed extremely low). This can also give an insight to study further if the same learning styles combinations put students on a similar academic performance status or not on some fundamental concepts in chemistry.

In general, the correlational statistics and regression analysis shows that there was no statistically significant relationship between academic performances on some fundamental concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure, an acid - base equilibrium and common thermodynamic terms and Felder-Silverman learning styles. A causal-comparative study conducted by Al-Jaroudi (2009) to see the relationship between learning styles and pre-service elementary teachers' conceptual understanding of chemistry and the nature of matter in a simulated learning environment showed no significant relationship between Felder-Silverman learning styles and achievement gain (Al-Jaroudi, 2009).

5.6 Comparing students' academic performance on some fundamental chemical concepts against Felder-Silverman learning styles

The second research question was "Which learning style best enhances students' academic performance in chemistry: Visual or Verbal learners; Sensing or Intuitive learners; Active or Reflective learners; Sequential or Global learners?" In addition to the indices of "β" coefficients presented in Tables 5.7 and 5.8, correlation coefficients presented in Tables 5.5 and 5.6, and an independent sample t-test was used to empirically answer this research question. The comparison of science students' academic performance against their learning style has been made using an independent sample t-test.

Comparisons of Visual and Verbal learners' academic performance scores on some fundamental concepts in chemistry

The comparison between Visual learners' and Verbal learners' academic performance on some fundamental concepts in chemistry was based on the research question: Which learning style best enhances students' academic performance in chemistry among grade 11 and 12 science students: Visual or Verbal learning style?

The β coefficients in Table 5.8 for grade 11 students ($\beta = -.058$, p-value = .465) shows that the contribution of Visual/Verbal learning style to students' academic performance on some fundamental concepts in chemistry was small. This small contribution of Visual/Verbal learning to students' academic performance on some fundamental concepts in chemistry was not statistically significant contributor. Thus, the β and p-value suggest that the contribution and probability of predicting academic performance in some fundamental concepts in chemistry from Visual/Verbal learning style dimension was not statistically significant. Although contributions of Visual/Verbal learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to further check whether being Visual or Verbal learner accounts for some significant differences in academic performance on some fundamental concepts in chemistry.

The data on grade 11 science students' academic performance on some fundamental concepts in chemistry is presented in Table 5.2. The table shows that the mean for academic performance on some fundamental concepts in chemistry was 11.72 for Visual, and 12.06 for Verbal learners. This shows that the differences between the means of the two groups (i.e. between the mean of Visual and Verbal learners) was 0.34. The question here is whether these differences were statistically significant or were due to chances. An independent sample t-test can help the researcher to answer this question. Therefore, the assumption of homogeneity of variances was tested on the data using the Levene's statistics (Leech, et al., 2005) before applying the result of a independent sample t-test (Table 5.13). The numerical results of the independent sample t-test are displayed in t-test summary table (Table 5.13). The table lists the assumptions of variances, difference between means, t-value, & the p-value.

Table 5.13 Output of Levene's test and t-test on academic performance of Grade 11 Visual/Verbal students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Performance	Equal variances assumed	.133	.715	.702	165	.484	.33783	.48135
	Equal variances not assumed			.703	140.103	.483	.33783	.48032

In Table 5.13, the Levene's statistics showed that the variances were not statistically significantly different, because the p-value of .715 was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied for further test on the difference between the means of measures of academic performance of Visual and Verbal learners.

As it can be seen in the Table 5.13, an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was t(165) =.702, p-value = .484. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference in academic performance on some fundamental concepts in chemistry between grade 11 Visual and Verbal learner in preparatory schools. My conclusion here is that being Visual or Verbal learner could not make any difference among grade 11 science students' test scores on some fundamental concepts in chemistry. Therefore, the difference observed between the means of grade11Visual and Verbal science students' academic performance (i.e. 0.34) in this study could be due to chance. Because, the independent sample t-test showed that whether the learners were being Visual or Verbal their academic performance on some fundamental concepts in chemistry was not statistically significant.

A similar comparison was made between the means of grade 12 Visual and Verbal learners' academic performance on some fundamental concepts in chemistry using an independent sample t-test and the collinearity statistics (see Table 5.7). The β coefficient (β= .141, p-value = .080) presented in Table 5.7 shows that the contribution of Visual/Verbal learning style to students' academic performance on some fundamental concepts in chemistry was very small. The p-value also shows that Visual/Verbal learning style was not statistically significant contributor to students' academic performance on some fundamental concepts in chemistry, because the p-value was marginally above α= .05. Therefore, the β and p-value indicated that the contribution and probability of predicting academic performance in some fundamental concepts in chemistry from Visual/Verbal learning style dimension was not statistically significant. Although the contributions of Visual/Verbal learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check whether being Visual or Verbal learner brings some differences in academic performance on some fundamental concepts in chemistry.

Table 5.3 presents that, the means for academic performance on some fundamental concepts in chemistry was 13.05 for Visual learners and 12.00 for Verbal learners. Hence, the difference between the means of Visual and Verbal was 1.05. The question here was that whether this means difference was statistically significant or was due to chances. An independent sample t-test can help the researcher to answer this question. The numerical results are displayed in t-test summary table (Table 5.14). The table lists assumptions of variances, difference between means, t-value, & the p-value.

Table 5.14 Output of Levene's test and t-test on academic performance of Grade 12 Visual or Verbal students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Academic performance	Equal variances assumed	2.100	.149	-1.705	157	.090	-1.05405	.61837
	Equal variances not assumed			-1.809	102.858	.073	-1.05405	.58280

As it can be read from Table 5.14, the variances were not statistically significant different, because the p-value of the Levene's test was .149 which was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied to conduct an independent sample t-test to check the statistical significance on the differences between the means of Visual and Verbal learners' measures of academic performance.

As it can be seen in the Table 5.14, output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was $t(165) = -1.705$, p-value = .090 and was not statistically significant. In other words, it can be concluded that there was no statistically significant difference between the means of Visual and Verbal learners' academic performance on some fundamental concepts in chemistry. My conclusion is that being Visual or Verbal learner did not reveal a statistically significant difference among Grade 12 science students' academic performance scores on some fundamental concepts in chemistry. This implies that the performance mean difference observed between Visual and Verbal learners in the study was due to chance.

Comparisons of Sensing and Intuitive learners' academic performance scores on some fundamental concepts in chemistry

The performance of Sensing and Intuitive students on some fundamental concepts in chemistry was compared using an independent sample t-test. The research question was: Which learning style best enhances students' academic performance in chemistry among grade 11 and 12 science students: Sensing or Intuitive?

β coefficients observed in Table 5.8 for grade 11 students (β= .028, p-value =.720) shows that Sensing/Intuitive learning style contribution to grade 11 students' academic performance on some fundamental concepts in chemistry was very small. The p-value also shows that Sensing/Intuitive learning style was not statistically significant contributor to students' academic performance on some fundamental concepts in chemistry among grade 11 science students. Therefore, the smallest β and p-value well above α=.05 suggest that the contribution and probability of predicting academic performance in some fundamental concepts in chemistry from Sensing/Intuitive learning style dimension was not statistically significant. Even though the contributions of Sensing/Intuitive learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check whether being Sensing or Intuitive learner accompanies with statistically significant differences in academic performance on some fundamental concepts in chemistry.

Table 5.2 presents the mean of scores on grade 11 students' academic performance on some fundamental concepts in chemistry for the Intuitive (11.73) and Sensing (11.90) learners. The difference between the mean of Sensing and Intuitive learners was still very small, which was

0.17. Therefore, the question here is that whether this difference was statistically significant or was due to chances. An independent sample t-test can help the researcher to answer this question. Therefore, the assumption of homogeneity of variances was checked using the Levene's statistic before using the Independent sample t-test (see the Table below 5.15).

Table 5.15 Output of Levene's test and t-test on academic performance of Grade 11 Sensing or Intuitive students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Performance	Equal variances assumed	.009	.923	-.313	165	.755	-.17264	.55205
	Equal variances not assumed			-.305	62.981	.761	-.17264	.56573

As it can be seen from Table 5.15, the Levene's statistics showed that the variances were not statistically significant, because the p-value was .923 which was greater than 0.05. Therefore, the assumption of homogeneity of variance was fulfilled for further statistical significance test of the difference between the means of measures of academic performance of Sensing and Intuitive learners via an independent sample t-test. The independent sample t-test numerical results are displayed in t-test summary table (Table 5.15). It lists the assumptions of variances, Difference between means, t-value, & the p-value.

As it can be seen in Table 5.15, the output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was: t(165)= -.313, p-value = .755. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference in academic performance on some fundamental concepts in chemistry between Sensing and Intuitive learners. My conclusion is that being Sensing or Intuitive learner couldn't make any difference in the students' test scores on some fundamental concepts in chemistry. Therefore, 0.17 difference in academic performance on some fundamental concepts in chemistry between the means values of Visual and Verbal learners in this study was due to chance. It was, because whether the learners were Sensing or Intuitive their academic performance on some fundamental concepts in chemistry was not statistically significant.

The similar test was applied to compare the mean difference between the Sensing and Intuitive learners' academic performance on some fundamental concepts among grade 12 science students. As it can be seen in collinearity statistics Table 5.7 (i.e. β=.053, p-value =.507), the Sensing/Intuitive learning style was not statistically significant contributor to students' academic performance on some fundamental concepts in chemistry among grade 12 science students. Because, the β coefficients was small and the p-value was well above $\alpha = 0.05$.

Thus, the β and p-value indicated that the contribution and probability of predicting academic performance on some fundamental concepts in chemistry from Sensing/Intuitive learning style was not statistically significant. Although, the contributions of Sensing/Intuitive learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to further check whether being Sensing or Intuitive learner resulted in statistical significant differences in academic performance on some fundamental concepts in chemistry.

Table 5.3 presents that, the means for academic performance on some fundamental concepts in chemistry was 12.80 for Sensing and 12.47 for Intuitive learners. The difference between the means of Sensing and Intuitive learners' academic performance on some fundamental concepts in chemistry was .39. The question here was that if this difference was statistically significant or was due chances. An independent sample t-test can help the researcher to answer this question. The numerical results are displayed in t-test summary table (Table 5.16). The table lists assumptions of variances, difference between means, t-value, & the p-value.

Table 5.16 Output of Levene's test and t-test on academic performance of Grade 12 Sensing or Intuitive students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Academic performance	Equal variances assumed	1.691	.195	-.519	157	.605	-.39562	.76238
	Equal variances not assumed			-.466	34.111	.644	-.39562	.84872

As it can be read in Table 5.16, the variances were not statistically significant different since the p-value of the Levene's test was .195 which was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied to test the difference between the means of measures of academic performance of Sensing and Intuitive learners using an independent sample t-test.

As it can be seen in the Table 5.16, output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was $t(165)=-.519$, p-value = .605. This was not statistically significant. In other words, it can be concluded that there was not statistically significant difference in academic performance on some fundamental concepts in chemistry between the Sensing and Intuitive learners in preparatory schools. This means being Sensing or Intuitive learner did not make any difference in the students' tests scores on some fundamental concepts in chemistry. Therefore, the performance mean difference between Sensing and Intuitive learners (i.e. .39) in the study was due to chance.

Of course, a study by Yeung, Read, Robert and Schmid (2006) on first year chemistry at the University of Sydney also reported similar result showing that being Sensing learner or Intuitive learner didn't influence students' performance in chemistry. The statistics of the empirical evidence produced in this study also revealed that Intuitive learners couldn't performed better than Sensing learners on the fundamental chemical concepts considered under this study.

As it has been discussed in the literature review section, Quenk (2009) argues that Sensing learners highly depend on and prefer direct experience and doing things than playing with theories and abstracts. Quenk maintains to explain that Intuitive learners prefer to learn concepts, ideas, theories, and inferring connections among diverse pieces of information. If Intuitive learners' preference to learn concepts (abstracts) affected their academic performance, the current study would show Intuitive learners to perform better than Sensing learners on some fundamental chemical concepts. However, the current study revealed that there was no statistically significant difference between Sensing and Intuitive learners in their academic performance on the fundamental concepts under investigation. This tends to imply that learning styles preference shouldn't be the first priority in making instructional decisions. Rather the priority should be given to the representational nature of chemical concepts.

Comparison of Active and Reflective learners' academic performance scores on some fundamental concepts in chemistry

The independent sample t-test was computed to observe if there was statistically significant difference in Active and Reflective learners' performance on some fundamental concepts in chemistry. The question asked is: Which learning style best enhances students' academic performance in chemistry for grade 11 and grade 12 science students: Active or Reflective?

In addition to the t-test comparison of means of Active/Reflective learners' academic performance among grade 11 science students, the indices of collinearity statistics presented in Table 5.8 are studied. As can be seen in the table, for Active/Reflective learning style dimension the β coefficient (β= .024, p-value =.762) was small and the p-value was above .05.

This minimum β and large p-value tell us that that the contribution or probability of predicting academic performance in some fundamental concepts in chemistry from Active/Reflective learning style was not statistically significant. Though the contributions of Active/Reflective learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check if being Active or Reflective learners resulted in statistically significant differences in academic performance on some fundamental concepts in chemistry among grade 11 science students.

Table 5.2 presents that mean of measures of academic performance on some fundamental concepts in chemistry was 11.88 for Active learners and 11.83 for Reflective learners. The difference between the means for Academic performance of Active and Reflective learners was .05. The question here was that whether these difference was statistically significant or was due chances. An independent sample t-test can help the researcher to answer this question. The numerical results are displayed in t-test summary table (Table 5.17). The table lists assumptions of variances, difference between means, t-value, & the p-value.

Table 5.17 Output of Levene's test and t-test on academic performance of Grade 11 Active or Reflective students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Performance	Equal variances assumed	.545	.461	-.113	165	.910	-.05308	.47142
	Equal variances not assumed			-.112	162.759	.911	-.05308	.47211

As can be seen in Table 5.17, the variances were not statistically significantly different because, the p-value of the Levene's test was .461, which was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied to conduct an independent sample t-test to compare the difference between the means of measures of academic performance of Active and Reflective learners.

As it can be seen in the Table 5.17, the output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$, was t(165)= -.113, p-value = .910. This was not statistically significant. In other words, it can be concluded that there was not statistically significant different academic performance on some fundamental concepts in chemistry between the Active and Reflective learners of preparatory schools. My conclusion is that being Active and Reflective learner did not bring any statistically significant difference among grade 11 science students' tests scores on some fundamental concepts in chemistry. This mean difference (0.05) between the academic performance of Active and Reflective learners in the study was due to chance; whether learners were Active or Reflective their academic performance on some fundamental concepts in chemistry was not statistically significant.

Similarly, an independent sample t-test was applied to compare the means of Active and Reflective learners' academic performance on some fundamental concepts among grade 12 science students. Moreover, the indices of collinearity statistics presented in Table 5.7 are considered.

The β coefficient presented in Table 5.7 for (β= -.045, p-value =.572) shows that the contribution of Active/Reflective learning style to grade 12 science students' academic performance on some fundamental concepts in chemistry was very small. The p-value also indicates that Active/Reflective learning style was not statistically significant contributor to students' academic performance on some fundamental concepts in chemistry among grade 12 students.

The β and p-value imply that the contribution and probability of predicting academic performance on some fundamental concepts in chemistry from Active/Reflective learning style dimension was not statistically significant. Although, the contributions of Active/Reflective learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check whether being Active or Reflective learner accompanies with differences in academic performance on some fundamental concepts in chemistry.

Table 5.3 shows that, the mean of academic performance on some fundamental concepts in chemistry was 12.59 for Active and 12.91 for Reflective learners. The difference between the mean of Active and Reflective learners' academic performance was .43. The question here was that whether this differences in academic performance was statistically significant different or was due chances. An independent sample t-test can help the researcher to answer this question.

The numerical results are displayed in t-test summary table (Table 5.18). The table lists the assumptions of variances, difference between means, t-value, & the p-value.

Table 5.18 Output of Levene’s test and t-test on academic performance of Grade 12 Active or Reflective students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Academic performance	Equal variances assumed	.024	.877	.553	157	.581	.31717	.57380
	Equal variances not assumed			.551	151.966	.582	.31717	.57551

As it can be seen in Table 5.18, the p-value of the Levene’s test was .877. The variances were not statistically significant different at α=0.05. Therefore, the assumption of homogeneity of variance was satisfied for further independent sample t-test on the difference between the means of measures of academic performance of Active and Reflective learners.

As it can be seen in the Table 5.18, the output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was t(165)= .553, p-value = .581. This was not statistically significant. In other words, it can be concluded that there was not statistically significant difference between the Active and Reflective learners’ academic performance on some fundamental concepts in chemistry. My conclusion was that being Active or Reflective learner did not make any difference in the students’ tests scores on some fundamental concepts in chemistry. This implies that the difference between Active or Reflective learners’ performance in the study was due to chance.

Comparisons of Sequential and Global learners' academic performance on some fundamental concepts in chemistry

An independent sample t-test was computed to observe the difference between Sequential and Global learners' academic performance on some fundamental concepts in chemistry. The research question was: Which learning style best enhances students' academic performance in chemistry among grade 11 and grade 12 science students: Sequential or Global learning style?

Besides the t-test, indices of the collinearity statistics presented in Table 5.8 were studied. The β coefficient for Sequential/Global learning style in Table 5.8 for grade 11 students (β= .092, p-value =.246) was small and the p-value was above.05.This shows that the Sequential/Global learning style was not statistically significant contributor to students' academic performance on some fundamental concepts in chemistry among grade 11 students. Thus, β and p-value for the predictor variable Sequential/Global learning style dimension suggests that the contribution and probability of predicting academic performance in some fundamental concepts in chemistry from Sequential/Global learning style dimension was not statistically significant. Although, the contributions of Sequential/Global learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to further check whether being Sequential or Global learner was a source of differences in academic performance on some fundamental concepts in chemistry.

Table 5.2 shows that the mean of academic performance on some fundamental concepts in chemistry was 11.49 for Sequential and 12.04 for Global learners. The difference between the mean of Sequential and Global learners' academic performance was .55. The question here was that to check if this differences was statistically significant or resulted due to chance. An independent sample t-test can help the researcher to answer this question. The numerical results are displayed in t-test summary table (Table 5.19). The table lists the assumptions of variances, difference between means, t-value, & p-value.

Table 5.19 Output of Levene's test and t-test on academic performance of Grade 1 Sequential or Global students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Performance	Equal variances assumed	.000	.987	1.090	165	.277	.54481	.49968
	Equal variances not assumed			1.082	105.416	.282	.54481	.50336

As it can be seen in Table 5.19, the variances were not statistically significant different, because the p-value of the Levene's test was .987 which was greater than 0.05. Therefore, the assumption of homogeneity of variance was satisfied for statistically significance test on the difference between the means of Sequential and Global learners' academic performance.

As it can be seen in Table 5.19, the output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was t(165)= 1.090, p-value = .277. This was not statistically significant. In other words, it can be concluded that there was no statistically significant difference between the means of Sequential and Global learners' academic performance on some fundamental concepts in chemistry. My conclusion is that being Sequential or Global learner did not make any difference on students' test scores on some fundamental concepts in chemistry. Therefore, the performance mean difference in the study was due to chance.

The same inferential statistical test was used to compare the means of grade 12 Sequential and Global learners' academic performance on some fundamental concepts. Moreover, the β coefficient presented in Table 5.7 was considered. The β coefficient (β= .029, p-value =.714) presented in Table 5.7 shows that Sequential/Global learning style contribution to grade 12 students' academic performance on some fundamental concepts in chemistry was very small. The p-value also indicates that this small contribution of Sequential/Global learning styles to grade 12 students' academic performance on some fundamental concepts in chemistry was not statistically significant.

Hence, the β and p-value suggest that the contribution and probability of predicting academic performance in some fundamental concepts in chemistry from Sequential/Global learning style dimension was not statistically significant. Although, the contributions of Sequential/Global learning styles dimension to the regression model was not statistically significant, an independent sample t-test was used to check if being Sequential or Global learner accompanied with statistically significant differences in academic performance on some fundamental concepts in chemistry.

Table 5.3 presents that, the mean for academic performance on some fundamental concepts in chemistry was 12.84 for Sequential and 12.69 for Global learners. The difference between the means of Sequential and Global learners' academic performance was .15. This difference was very small, but the question here was that, was this difference statistically significant or resulted due to chances. An independent sample t-test can help the researcher to answer this question. The numerical results for statistical significance test are displayed in t-test summary table (Table

5.20). The table lists the assumptions of variances, difference between means, t-value, & the p-value.

Table 5.20 Output of Levene's test and t-test on academic performance of Grade 12 Sequential or Global students

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Academic performance	Equal variances assumed	.008	.927	-.235	157	.814	-.14583	.62035
	Equal variances not assumed			-.229	86.981	.819	-.14583	.63626

As can be seen in Table 5.20, the p-value of the Levene's test was .927 at α=0.05. This shows that the homogeneity variances were not statistically significantly different. Therefore, the assumption of homogeneity of variance was satisfied for an independent sample t-test on the difference between the means of Sequential and Global learners' academic performance.

As it can be seen in the Table 5.20, the output of an independent sample t-test based on the assumptions of equal variance at $\alpha = 0.05$ was t(165)= -.235, p-value = .814. This was not statistically significant. In other words, it can be concluded that there was not statistically significant difference in academic performance on some fundamental concepts in chemistry between the Sequential and Global learner in preparatory schools. My conclusion is that being Sequential or Global learner did not make any difference in students' tests scores on some fundamental concepts in chemistry. This implies that, the observed difference between means Sequential and Global learners' academic performance (i.e. .15) was due to chance.

In general comparison of means between Visual and Verbal learners', Sensing and Intuitive learners', Active and Reflective learners', and Sequential and Global learners' academic performance on some fundamental concepts at both grade levels was not statistical significant at $\alpha = 0.05$. Therefore, the current data on the second research question suggested that there was not a particular type of learning style that helped natural science students to excel in their academic performance on some fundamental concepts in the topics Atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms.

5.7 Summary

In the quantitative phase of the study two research questions were addressed. The data was analyzed using a descriptive and inferential statistics. The finding of this part of the study is briefly summarized as follows.

Regarding the distribution of students across learning styles the study revealed that the majority of (more than 50%) grade 11 and 12 natural science students were Visual (65.03%), Sensing (79.44%), Active (52.15%) and Global (68.10%) learners. This result was comparable with results of other studies except for distribution of students on the Sequential/Global learning style dimensions.

Concerning students' academic performance against Felder-Silverman learning styles, the mean, standard deviation and confidence interval at 95% of both grade 11 and grade 12 science students' academic performance on some fundamental concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms shows a small difference. This means that small difference in academic performance on some fundamental concepts in chemistry was observed between Visual and

Verbal learners, Sensing and Intuitive learners, Active and Reflective learners, and Sequential and Global learners.

Moreover, the correlation coefficients between Visual/Verbal learning styles and academic performance, Sensing/Intuitive learning styles and academic performance; Active/Reflective learning styles and academic performance and, Sequential/Global learning styles and academic performance were below 0.3 for both grade 11 and 12 natural science students. None of these relationships were statistically significant at $\alpha = 0.05$ but between Visual/Verbal learning style and academic performance on some fundamental concepts in chemistry among grade12 science students.

In the case of grade 12 natural science students, there was marginally statistically significant relationship between Visual and Verbal learners' academic performance at $\alpha = 0.05$ ($r_2 = .135$, $p=.045$). However, the correlation coefficient ($r_2 = .135$) shows that the relationship between Visual/Verbal learning style and academic performance on some fundamental concepts was very low, which was well below 0.3.

The data was further subjected to regression model fit test. The predictor (independent) variables of the model were the four dimensions of Felder-Silverman learning styles: Visual/Verbal; Sensing/Intuitive; Active /Reflective and Sequential/Global dimensions. The criterion (dependent) variable was academic performance on some fundamental concepts in chemistry. The regression model equation was:

$$\text{Academic Performance} = \beta_0 + \beta_1 \text{ (Visual/Verbal)} + \beta_2 \text{ (Sensing/Intuitive)} + \beta_3 \text{ (Active + Reflective)} + \beta_4 \text{ (Sequential/Global)} + \epsilon.$$

The output of the regression model fit test in the Regression Model Summary showed that R square was .012 for grade 11 and .024 for grade 12 natural science students. This implies that about 1.2 % variation in academic performance on some fundamental concepts in chemistry among grade 11 natural science students was explained by Felder-Silverman learning styles model and 2.4% variation in academic performance on some fundamental concepts in the topics: acid-base equilibrium and common thermodynamic terms among grade 12 students was explained by Felder-Silverman learning styles. It means that the remaining, 98.8% (for grade 11) and 97.6% (for grade 12) variations in academic performance on the fundamental concepts under investigation were more likely to be explained by variables other than Felder-Silverman's learning styles.

The ANOVA part of the regression model fit test for both grade level students' showed that 1.2% (for grade 11) and 2.4% (for grade 12) variation in or prediction of academic performance on some fundamental concepts among natural science students was not statistically significant at $\alpha = 0.05$. Therefore, as the computations of R squares and significance tests at $\alpha = 0.05$ for both grade levels showed that the regression model was poor to explain students' academic performance on some fundamental concepts in the topics from Sensing/Intuitive, Visual/Verbal, Active/Reflective and Sequential/Global dimensions of Felder-Silverman's learning styles model.

In relation to the second research question, the current study examined if there were a statistically significance difference in academic performance on some fundamental concepts in chemistry due to differences in students' learning styles. An independent sample t-test on student's academic performance on some fundamental concepts in chemistry showed that, there was not statistically significant difference in academic performance between Visual and Verbal or Sensing and Intuitive or Active and Reflective or Sequential and Global learning learners, at $\alpha = 0.05$. The beta (β) coefficients of the correlational statistics also show that Felder-Silverman learning styles were not a statistically significant contributor to science students' academic performance on some fundamental concepts in chemistry. Therefore, the current data on the second research question suggested that there was not a particular type of learning style that helped natural science students to excel in their academic performance on some fundamental concepts in the topics Atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms.

Based on the quantitative phase of the study, the researcher concluded that there was not a particular learning style that helps students to be success in learning some fundamental chemical concepts considered under the investigation. Moreover, the empirical data of the quantitative part of study failed to suggest a learning style model specific for chemistry education.

5.8 Results of the qualitative phase of the study

5.8.1 The nature and role of chemistry instructional material on academic performances: Experiences from students

Instructional materials are among variables which could influence learners' academic performance. Thus, qualitative phase of the current study was conducted to explore the role of instructional materials on students' academic performance on some fundamental concepts in chemistry. Based on the experiences and views of participants, some common features of chemistry instructional materials used in both schools that helped to improve students' academic performance in chemistry were identified (see Table 5.21).

Table 5.21 The nature of chemistry instructional materials preferred by participants

Variable: the main stem that goes from **question 1** through **question** 3 is :	Number (n) of participants
The characteristics of instructional material(s) which determine my current performance in chemistry is/are explained by its/their emphasis given to:	
Question1:	
A. diagrammatic, symbolic, molecular & structural formula, model and mathematical representations of chemistry.	12
B. textual explanations /words presentation of chemistry	3
Question 2:	
A. practical activities	9
B. conceptual and theoretical explanation of chemistry	6
Question 3:	
A. Chemical concepts and theories through mathematical relations or representations in a summarized manner.	10
B. the details of chemical concepts and theories through oral or textual presentation	4

As it is shown in Table 5.21, Question 1 was concerned with the nature of instructional material which can be characterized by Visual/Verbal form of information organization and presentation. As it can be seen from the participants response, the majority of students selected “A” and they claim that visually presented instructional materials helped them to perform better. This refers to the instructional materials which were characterized by diagrammatic, mathematical and symbolic representations, molecular and structural formulas presentations were beneficial to students.

The students were further requested to provide reason(s) for their choice. Some of their responses are presented as follows.

294PEL: because, instruction delivered via diagram or laboratory helped me to acquire more knowledge

325PEH: Because of practical activities and experiments, mathematical formulas, expressions are clearly and step-by-step presentations of the new student's chemistry textbook, it helped me to learn more. Moreover, molecular formulas and structures are depicted well in student's textbook.

"287PEH": because chemistry is an interesting subject. Therefore, I am pleased by chemistry classes which helped to my current performance.

311PEL: As the nature of chemistry suggests, teaching-learning process in chemistry has to emphasize or focused on teaching through diagrammatical, symbolic/atomic representations and models, and chemical formulas and structures is useful and helped students to grasp chemistry easily

155PEH: Because chemistry studies about elements and their structures, therefore, learning chemistry through its symbolic, model and mathematical representations can create suitable learning environment for successful performance in chemistry

266PEL: because learning chemistry though diagrams, atomic representation, models can help to achieve better in chemistry. Moreover, practical activities/work contributes more to chemistry learning than theoretical explanations.

297PEH: because things taught through diagrams, symbols and mathematical representations are helpful to easily remember. However, oral presentations and lectures can easily be lost.

On other hand some few participants selected choice "B". Choice B stated about the nature of instructional material characterized by emphasizes it gives to textual explanation and oral description to chemistry concepts and that could improve academic performance. Some of their responses and justifications were:

57PEH: because those presented in picture and diagram is not understandable unless presented textually or orally.

106PEL: because make up classes, handout, practical questions (sheet) can be more useful. The current teaching-learning process is good.

In question 2, participants were asked about the nature of instructional material in terms of the form of information organization and presentation that can affect their perception preferences. As it can be seen in Table 5.21, the majority of participants selected choice "A". Choice "A" states about the nature of instructional material which was characterized by emphasizes they gave to practical activities over concepts and theories that helped them to perform better in chemistry. The participants were requested to provide reason(s) of their choice. Their justifications for their answers are presented as follows.

35PEM: because I learn chemistry much better when I am taught through practical work first. Therefore I prefer to learn chemistry through practical works/activities.

37PEM: Practical work and graphic based presentation of chemistry is good for me. It could also be good if the teacher prepares teaching aids too.

36PEL: Practical work, diagram, molecular formula and structure and atomic representations characterize chemistry. Therefore, I prefer to learn in such form.

106PEL: Laboratory work supported chemistry teaching can be more useful to me. Therefore it is good to learn through practical work.

325PEH: Because of the fact that if I learned things through the help of laboratory (practical work) it would be easy for me to remember and perform well.

222PEH: because chemistry learning through practical activities/work is long lasting and also a base to learn/understand chemical concepts. Practice based teaching of chemistry can make more successful than theoretical explanations.

267PEL: because I believe practical based teaching of chemistry can help to learn better than textual or oral (word) presentations.

However, the remaining six participants selected “B”. Choice “B” states about the nature of instructional material which is characterized by the emphasis it gives to conceptual and theoretical explanations that improved their performance. Therefore, this shows that they prefer learning concepts and theories to practical activities through instructional materials which could give adequate explanations. Some of the justifications to their choice were:

155PEH: ... because, although student’s chemistry textbook suggests practical activities/work, due to the existing constraints I have learned theoretical and chemical concepts through explanatory presentations.

294PEL: because, chemistry instruction mainly focused on teaching chemistry concepts in detail, I learned more and it helped me for my current performance.

287PEH: because I prefer to practical activities to theoretical and conceptual explanations/representations.

311PEL: one of the reasons that helped me to understand chemistry is explanatory presentations of chemistry concepts and theories through words. Therefore I have selected "b" as it reinforces my choice.

57PEH: Teaching theories and concepts helps to understand practical works. Therefore, I prefer first to learn theories and concepts.

In **Question 3,** participants were asked about the nature of chemistry instructional materials in relation to their organizational sequence. Out of 15 participants, 14 responded to question 3. The majority of these participants selected "A". They justified that instructional material which present chemistry concepts and theories in mathematical forms of relations and in a summarized way were useful to them to perform better in chemistry. Their justifications to their choice were:

325PEH: because, understanding the chemical concepts first helped me a lot to understand their mathematical representations and their relationships can be easily understood from their mathematical representations.

287PEH: because once I have learned theory through mathematical representations, it is easy for me to give explanations through mathematical representations.

311PEL: chemistry like any other subjects can be represented mathematically. After the theoretical and conceptual presentations to the class, presenting it mathematically can make chemistry education very correct and easy to understand. It is why I chose "a".

222PEH: Mathematical representations and expressions can present chemical concepts comprehensively. Therefore, to understand chemical concepts and to be successful mathematical representations of chemistry is very helpful.

57PEH: because, when chemistry is represented mathematically, it helps me to understand easily. Textually represented explanations are difficult to understand compared to mathematical represented chemistry.

35PEM: because I can better understand chemical concepts and theories and I am more engaged when they are presented in the form of mathematical representations.

37PEM: when it is taught mathematically like mathematics I couldn't forget it.

36PEL: Concept and theory of chemistry has its own mathematical expression and is a mathematical (quantitative) subject. Therefore, presenting chemistry mathematically is more easily understandable for me.

However, few of the remaining participants selected “B”. Their response showed that if a chemistry instructional materials present chemical concepts and theories in the form of textual explanations and lecture, it would be helpful to them to improve their academic performance in chemistry. Their justifications were:

233PEM: Chemistry teaching is aimed to teach subjects of chemistry and chemical concepts that form chemistry. Therefore, mathematical representations can clearly represent the chemical concepts and their relationships. Mathematical representation presents interrelationships among the chemical concepts.

106PEL: our teacher presents chemistry in a good and motivated way. Therefore I expect this could be continued.

294PEL because, it helped me to improve my current performance partially or fully, the presentation of the chemical concepts is very helpful because it is detail and.

In sum, participants’ response to those three semi-structured questions showed that the majority of students were more comfortable to learn from instructional materials characterized by emphasis it gives to visual or pictorial forms of presentations, practical or concrete forms of presentations, and summarized and holistic ways of presentation of chemical theories and concepts. Diagrams, chemical symbols, molecular structures and formulas, practical activities, mathematical or relational representations of chemical concepts and theories, and summaries were important characteristics of the instructional materials which helped them to perform better in chemistry.

Hence, the qualitative part of the study showed that natures of chemistry instructional material used in the schools were the comfortable to the majority of students. This finding was actually comparable to the findings in the quantitative part of the study that revealed the majority of students were Visual, Sensing, Intuitive and Global learners. In other words, the qualitative part of the study showed that the majority of participants were Visual, Sensing, Intuitive, and Global learners' and they preferred the same nature of chemistry instructional materials. On the contrary, there were some students who were comfortable to learn from the nature instructional materials characterized by the emphasis it gives to textual explanations over visual presentations, conceptual and theoretical explanations over practical activities, detailed and step by step explanations over holistic or summarized forms of presentations. Therefore, this result was subjected to further analysis to see if there were any systematic and meaningful pattern that shows relationship between students' level of academic performance and differences in their preferences to the different natures of chemistry instructional materials used in their schools. As a result, experiences of participants on the nature of chemistry instructional materials used in the schools were further analyzed by braking down into different sections. The sections were organized into two based on students' learning styles combinations and level of academic performance on the fundamental concepts in chemistry. In other words, it was organized into:

1) Experiences from students with extremely high or low academic performance, and

2) Experiences from students with the same learning style

5.8.1.1. Experiences from students with extremely high or low academic performance

Extremely high and extremely low performing students' experience about the nature and role of chemistry instructional materials on their academic performance were organized based on their academic performances into two. Their responses to the questions Because; it was helpful to observe if there was/were any difference in their instructional experience which led them to perform extremely different on the same test constructed from the same fundamental concepts in chemistry, and taught under the same instructional settings. Therefore, the nature of chemistry instructional material which contributed to extremely low or extremely high academic performance in chemistry is summarized in Table 5.22. Here, students' who were performing extremely high (PEH) on the test were coded as PEH, and students' who were performing extremely low (PEL) on the test were coded as PEL.

Table 5.22 The nature of chemistry instructional materials explained by students with extremely different performances

Variable: the main stem that goes from **question 1** through **question** 3 is :	Number of **PEL** participants who selected	Number of **PEH** participants who selected
The characteristics of instructional material(s) which determine my current performance in chemistry is/are explained by its/their emphasis given to:		
Question1:		
A. diagrammatic, symbolic, molecular & structural formula, model and mathematical representations of chemistry.	5	5
B. textual explanations /words presentation of chemistry	1	1
Question 2:		
A. practical activities	4	3
B. conceptual and theoretical explanation of chemistry	2	3
Question 3:		
A. Chemical concepts and theories through mathematical relations or representations in a summarized manner.	3	5
B. the details of chemical concepts and theories through oral or textual presentation	2	1

PEL participants' response on Question 1

As it can be seen in Table 5.22, concerning the responses of participants to question 1, out of six participants five of them selected "A". This implies that PEL students perform better in chemistry if the nature of instructional materials give emphasize to diagrammatic, symbolic and model representations, and use molecular formula and structures. Their justifications were:

294PEL: because, instruction delivered via diagram or laboratory helped him to acquire more knowledge.

311PEL: As the nature of chemistry suggests, chemistry education has to emphasize or focused on teaching through diagrammatical, symbolic/atomic representations and models, and chemical formulas and structures is useful and helped students to grasp chemistry easily. Moreover, chemistry like any other subjects can be represented mathematically. After the theoretical and conceptual presentations to the class, presenting it mathematically can make chemistry education very correct and easy to understand. It is why I chose "a".

266PEL: because learning chemistry though diagrams, atomic representation, models can help to achieve better in chemistry. Moreover, practical activities/work contributes more to chemistry learning than theoretical explanations.

36PEL: Chemistry can be well explained by its chemical formulas and structures which constitute its identity. Concept and theory of chemistry has its own mathematical expression and is a mathematical (quantitative) subject. Therefore presenting chemistry mathematically is more easily understandable for me.

106PEL: Make up classes, handout, practical questions (sheet) can be more useful. The current teaching-learning process is good.

However, the remaining participant selected "B" and gave the following reason for his/her choice.

106PEL:, make up classes, handout, practical questions (sheet) can be more useful. The current teaching-learning process is good.

PEH participants' response on Question 1

Six PEH participants responded to Question 1. As it can be seen in Table 5.22 five of the six PEH participants selected choice "A" of question 1. Choice "A" of question 1 states that the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis given to diagrammatic, symbolic, molecular and structural formula, model and mathematical representation of chemistry. Some of their responses to the question are presented as follows.

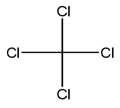
325PEH: Because of practical activities and experiments, mathematical formulas, expressions are clearly and step-by-step presentations of the new student's textbook it helped me to learn more. Moreover, molecular formulas and structures are depicted well in student's textbook.

155PEH: Because chemistry studies about elements and their structures, therefore, learning chemistry through its symbolic, model and mathematical representations can create suitable learning environment for successful performance in chemistry.

297PEH: because things taught through diagrams, symbols and mathematical representations are helpful to easily remember. However, oral presentations and lectures can easily be lost.

222PEH: Because, out of the instructional materials/method I used to learn through picture, diagrammatical and model representations relatively more comfortable/suitable to my mind create good opportunity to learn and hence helped me to understand. Because, a single picture can talk more than many words can do. … if things presented diagrammatically or pictorially I can easily learn it that goes with the saying that "a picture stands for thousand words". One picture can be comprised of many words and can pass wider and more comprehensive idea. Therefore pictorial (visual) presentations can lead to better result than materials given more emphasis to textual or oral explanations.

233PEH: Example, mathematically, CCl_4,



tetrachloromethane

Diagrammatical representation of tetrachloromethane Indicates tetrahedral shape in electro geometry structures, and the symbolic representations of Na, Mg, and Al indicates Sodium, Magnesium, Aluminum, respectively. From question 4c.

One of the PEH participants selected "B". Choice B stated that the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis given to textual explanation/word presentation of chemistry. The following reason was advanced by the student:

57PEH: those presented in picture and diagram is not understandable unless presented textually or orally. The majority of them give emphasis to textual (word) expiations. Student's chemistry text book does the same for me.

In general, from responses of participants to question1 the researcher learned that the majority of both PEL and PEH participants prefer the same characteristics of instructional material. However, their academic performance is extremely different. This further implies that students' differences in academic performance scores on some fundamental concepts in chemistry were not determined by the type of their instructional preference.

PEL participants' Responses on Question 2

As can be observed from Table 5.22, four extremely low performing (PEL) participants selected option "A" for question 2. The reasons of their choices are:

36PEL: Practical work, diagram, molecular formula and structure and atomic representations characterizes chemistry. Therefore, I prefer to learn in such form.

106PEL: Laboratory work supported chemistry teaching can be more useful to me. Therefore it is good to learn through practical work. Focusing on some concrete ideas using easy language, preparing books and providing is very good.

267PEL: because I believe practical based teaching of chemistry can help to learn better than textual or oral (word) presentations.

266PEL: Laboratory work, because it helps to observe the chemical changes and occurrences and is very helpful. Laboratory work helps to realize (prove) what has been taught theoretically in the classroom. Therefore, we can be easily convinced. As a result practical work can be useful to understand chemistry.

But, two extremely low performing (PEL) participants selected choice "B" in question 2. Their reasons of choice are presented as follows.

311PEL: one of the reasons that helped me to understand chemistry is explanatory presentations of chemistry concepts and theories through words. Therefore I have selected "b" as it reinforces my choice.

294PEL: Because, I learn more from chemistry teaching, which mainly focused on the details of chemistry concepts and it helped for my current performance.

PEH participants' Response on Question 2

Out of PEH participants who responded to question 2, four of them selected choice "A". Choice "A" of question 2 stands for the statement: the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis on practical activities. Some of their justifications to their choices are presented as follows.

> *325PEH: Because of the fact that I learned things through the help of laboratory (practical work) it helped me to remember and perform well. Practical work based instruction was important to me not to forget. The plasma instruction & diagrammatical presentations are very useful to understand well.*

> *222PEH: because chemistry learning through practical activities/work is long lasting and also a base to learn/understand chemical concepts. Practice based teaching of chemistry can make more successful than theoretical explanations. Practical activities/work and teaching aids by teacher are relatively more productive than others. Because laboratory based clearing are long lasting and the base for chemistry learning.*

However, two PEH participants selected choice "B" of question 2. Choice "B" stands for the statement: the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis given to conceptual and theoretical explanation of chemistry. Some of the justifications to their responses are presented as follows.

> *155PEH: because, although student's chemistry textbook suggests practical activities/work, due to the existing constraints I have learned theoretical and chemical concepts through explanatory presentations. Chemistry instructional materials which give more emphasis to textual explanations or oral presentations can make chemistry clearer and understandable. Every time, these instructional materials can help to maintain quality of education.*

> *57PEH: Teaching theories and concepts helps to understand practical works. Therefore, I prefer first to learn theories and concepts.*

The study of both PEL and PEH participants' responses to question 2 confirm that the majority of them selects "A" and provide similar justifications to their choice. This tells us that the majority of students have the same kind of preference towards chemistry instructional materials. However, the same preference towards instructional materials did not help them to narrow down their differences in academic performance on some fundamental chemical concepts considered under this investigation.

PEL participants' response on Question 3

As it can be seen in Table 5.22, three PEL participants selected choice "A" of question 3. This choice represents the nature of instructional material which could positively influence their academic performance and is characterized by the emphasis it give to a mathematical and summarized way of presenting chemical concepts and theories. The full responses of the participants are presented as follows.

311PEL: chemistry like any other subjects can be represented mathematically. After the theoretical and conceptual presentations to the class, presenting it mathematically can make chemistry education very correct and easy to understand. It is why I chose "a".

266PEL: Teacher's giving and working of summary questions helped more understanding. This guides us how to prepare ourselves and to get more knowledge.

On the other hand, two PEL students selected choice "B" of question three. This choice refers to the characteristics of instructional material which determine my current performance in chemistry was/were explained by its/their emphasis given to detailed and step-by step presentation of chemical concepts. Some of the details of responses of students who selected choice "B" are presented as follows.

294PEL: because, it helped me to improve my current performance partially or fully. And, the presentation of the chemical concepts is very detail and helpful. Chemistry books that give first details followed by practical works and then group work are very important instructional resources that need to be arranged.

267PEL: First to learn something, we have to prepare instructional materials which can: 1) give detail explanation to the matter under consideration; 2. Practical supported theoretical explanations; and 3. Explain the purpose of the theoretical presentation and practical work.

PEH participants' response on Question 3: Sequential/Global (Sensing/Intuitive)

As it can be shown in Table 5.22, four PEH participants selected choice "A" of the third question. Choice "A" of question 3 refers to the characteristics of instructional material which determine my current performance in chemistry is/are explained by the emphasis it/they give to chemical concepts and theories through mathematical relationships in a summarized way/manner. The full responses of some of the participants are presented as follows.

325PEH: because, understanding the chemical concepts first helped me a lot to understand their mathematical representation and hence their relationships can be easily understood from their mathematical representations.

287PEH: because once I have learned theory through mathematical representations, it is easy for me to give explanations through mathematical representations.

297PEH: because, if I have learned chemical concepts integrated with mathematical formula/representations, I can easily understand it and it is not forgettable.

222PEH: Mathematical representations and expressions can present chemical concepts comprehensively. Therefore, to understand chemical concepts and be successful mathematical representations of chemistry is very helpful to me.

57PEH: because, when chemistry is represented mathematically, it helps me to understand easily. Textually represented or explanations of chemistry are difficult to understand compared to mathematical representation of chemistry.

One participant selected choice “B” of question 3. Choice “B” refers to the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis given to the details of chemical concepts through oral or textual presentation.

155PEH: although chemistry is a natural science, lecture and detail notes about theories and chemical concepts helped me to acquire comprehensive chemical knowledge. Therefore, oral presentations (lecture) and explanations are important to acquire knowledge. Chemistry instructional materials which give more emphasis to textual explanations or oral presentations can make chemistry clearer and understandable. Every time, these instructional materials can help to maintain quality of education. For example, student’s chemistry textbook and teaching aid prepared by the teacher give explanation about the content of the subject; therefore they present the subject suitable and easily understandable.

Similarly, the study of both PEL and PEH participants’ response to question 3 revealed that the majority of them selected “A” and provide reason for their choice. This verifies that the majority of the participants’ preferences to the same nature of chemistry instructional materials are similar.

In sum, the analysis of the data on students' preference to the nature of chemistry instructional materials used in the schools showed that students' level of academic performance on the tests did not show any kind of systematic and meaningful pattern of association with a particular kind of preference to a particular nature of instructional materials used in the schools. Because participants' response from question 1 through 3 proves that there were many PEL and PEH students who have the same preference towards the nature of chemistry instructional materials used in the schools. However, students academic performance on the tests constructed from the same fundamental chemical concepts were extremely different. For example, the majority of PEL and PEH students were more comfortable to learn from chemistry instructional materials which gave emphasis to visual or pictorial forms of presentations, practical or concrete forms of presentations, and summarized and holistic ways of presentation of chemical theories and concepts. But their academic performances on the tests were extremely different. That means some performed extremely high and other performed extremely low.

Moreover, there were some PEL and PEH students who were comfortable to learn from the kind of chemistry instructional material which gave emphasis to textual explanations over visual presentations, conceptual and theoretical explanations over practical activities, detailed and step by step explanations over holistic or summarized forms of presentations. Still this shows that their level of academic performance on the fundamental chemical concepts did not show a similar pattern to their preferences to chemistry instructional materials. Therefore, to further buttress this observation, the data on PEL and PEH students with the same learning styles combinations was presented and analyzed separately.

5.8.1.2 Experiences from students with the same learning style

The quantitative phase of this study revealed that there were some students with the same learning style combinations but who had extremely different academic performance on the tests constructed from some fundamental concepts in chemistry (see Table 5.4). Regardless of the same learning styles combinations, and taught under the same instructional context in the schools, there were students whose academic performances on some fundamental chemical concepts considered in this study were extremely different. For example, as it can be seen in Table 5.4 cases 325PEH and 294PEL, and cases 287PEH and 311PEL were some of the pairs of participants with the same learning styles but who had extremely different academic performance on the tests constructed from some fundamental concepts in chemistry. Moreover, Cases 325PEH and 287PEH refers to participants who performed extremely high while Cases 294PEL and 311PEL refers to participants who performed extremely low on some fundamental chemical concepts considered in this study. If so how and which characteristics of chemistry instructional materials influence their academic performance, if any?

Same learning style participants' response on Question 1

All of the participants with same learning styles responded to question 1. All of the participants selected choice "A" of Question 1 which states that the characteristics of instructional material which determine my current performance in chemistry is/are explained by its/their emphasis given to diagrammatic, symbolic, molecular and structural formula, model and mathematical representation of chemistry. The full responses of some of the participants are presented as follows.

294PEL: because, instruction delivered via diagram or laboratory helped him to acquire more knowledge

325PEH: Because of practical activities and experiments, mathematical formulas, expressions are clearly and step-by-step presentations of the new student's textbook it helped me to learn more. Moreover, molecular formulas and structures are depicted well in student's textbook

287PEH: because chemistry is an interesting subject. Therefore, I am pleased by chemistry classes which helped my current performance.

311PEL: As the nature of chemistry suggests, chemistry education has to emphasize or focused on teaching through diagrammatical, symbolic/atomic representations and models, and chemical formulas and structures is useful and helped students to grasp chemistry easily. Moreover, chemistry like any other subjects can be represented mathematically. After the theoretical and conceptual presentations to the class, presenting it mathematically can make chemistry education very correct and easy to understand. It is why I chose "a".

Same learning style participants' response to Question 2

All of these participants responded to question 2. All participants but one selected choice "B" of question 2. They preferred instructional materials characterized by its/their emphasis given to conceptual and theoretical explanation of chemistry. The full responses of some of the participants are presented as follows.

294PEL: *because, chemistry instruction mainly focused on teaching chemistry concepts in detail, I learned more and it helped me for my current performance.*

325PEH: Because of the fact that I learned things through the help of laboratory (practical work) it helped me to remember and perform well.

287PEH: because I prefer to practical activities to theoretical and conceptual explanations/representations.

311PEL: one of the reasons that helped me to understand chemistry is explanatory presentations of chemistry concepts and theories through words. Therefore I have selected "b" as it reinforces my choice.

Same learning style participants' response on Question 3

All of these participants responded to question three. All participants but one selected choice "A" of question three. They preferred instructional materials characterized by its/their emphasis given to conceptual and theoretical explanation of chemistry. The participants' responses are presented as follows.

294PEL: because, it helped me to improve my current performance partially or fully, the presentation of the chemical concepts is very detail and helpful.

325PEH: because, understanding the chemical concepts first helped me a lot to understand their mathematical representations and their relationships can be easily understood from their mathematical representations.

287PEH: because once I have learned theory through mathematical representations, it is easy for me to give explanations through mathematical representations.

311PEL: Chemistry like other subjects can be represented mathematically. After the theoretical and conceptual presentations to the class, presenting it mathematically can make chemistry education very correct and easy to understand. It is why I chose "a".

In these groups of participants, all except one preferred the same nature of instructional materials. The nature of chemistry instructional materials which they explained as helpful to their performance were characterized by visual or pictorial forms of presentations, to conceptual and theoretical explanations practical or concrete forms of presentations, and summarized and holistic ways of presentation of chemical theories and concepts.

The foregoing analysis showed that students with the same learning styles were exposed to the same chemistry instructional materials. As a consequence, the researcher was expecting to observe similar pattern of academic performance on tests constructed from some fundamental concepts in chemistry among students with the same learning styles. However, some of the students performed extremely high and others performed extremely low. Therefore, to explore this unexpected result of the study and to check if there were any justifications related to the nature of common chemistry instructional materials used in their schools further examinations of the instructional contexts were conducted.

5.8.2. The nature of common chemistry instructional materials in the schools and their role on students' academic performance in chemistry

The two questions (see appendix B) about common instructional materials used in the schools and presented to students were: 1) list the most helpful and the least helpful chemistry instructional material to your academic performance in chemistry and 2) write their characteristics. Based on the participants' responses to these two questions, I have organized the responses into most or least helpful commonly used chemistry instructional materials in the schools (see Table 5.23) and their respective characteristics are presented in the subsequent paragraphs.

The most or least helpful commonly used chemistry instructional materials

The most or least helpful and commonly used chemistry instructional materials in both schools were Plasma TV instruction; student's chemistry text book, practical work, and teaching aid and their utilizations (see Table 5.23).

Table 5.23 The most or least helpful common chemistry instructional materials in the schools

No.	List of chemistry instructional material	Frequency mentioned by PEL	Frequency mentioned by PEH	Frequency mentioned by PEM	Total
1	Plasma TV instruction	21	17	9	47
2	Student's chemistry text book	11	25	8	44
3	Practical work/learning lab.	16	23	7	46
4	Teaching aids and their utilizations	12	11	5	28

As it can be shown in the Table 5.23, Plasma TV instruction, Student's chemistry text book, Practical work/learning Lab., and Teaching aids and their utilizations were the most commonly used chemistry instructional materials by students in both schools to learn chemistry. Participant students characterized these instructional materials based on the extent of academic benefit they acquired through these instructional materials. Therefore, I have presented the descriptions given by them about the characteristics of these instructional materials by organizing as most helpful or least helpful characteristics of chemistry instructional materials.

Here most helpful instructional material refers to those instructional materials which could have a positive contribution to students' academic performance on some fundamental chemical concepts considered under this investigation. On the other hand, least helpful nature of chemistry instructional materials refers to the characteristics of instructional materials which contributed least to students' academic performance in chemistry. What characteristics of student's chemistry text book, practical work and plasma TV based instruction made them most helpful or least helpful? Participants' responses to these questions are presented as follows.

The most helpful characteristics of chemistry instructional materials used in the schools

Participants were asked to list and describe the nature of chemistry instructional material which contributed to the enhancement of their academic performance in chemistry. The question was:

Question 4: From the chemistry instructional materials (i.e. your textbook, television instruction, practical/laboratory activities and teaching aids) in use by your school;

A. Please list chemistry instructional materials you consider most helpful to your current performance in chemistry in their order of importance?

B. Please describe the characteristics of chemistry instructional materials you listed under "4A", with regard to their emphasis to diagrammatic, symbolic, molecular structures & formulas, models and mathematical presentations?

C. Please describe the characteristics of chemistry instructional material(s) you listed under "4A", with regard to it/their emphasis to textual and oral presentations?

D. Please mention any essential characteristics of chemistry instructional materials that you consider most helpful to your current performance in chemistry, if not mentioned yet?

In response to these questions, the participants listed and described the most helpful characteristics/nature of the most commonly used chemistry instructional materials in the schools. In addition to these instructional materials, they also explained that teaching methods such as a student tutor by a one to five grouping of students and teachers' presentation/lecture were among the most helpful features. The details of the descriptions given about the nature of each of these instructional materials (i.e. Television (TV) instruction, student's chemistry text book, practical work, teaching aid and utilization by teachers) are presented independently in the following subsequent separate sections.

The most helpful natures of TV based chemistry instruction

TV based chemistry instruction was among one of the most commonly used chemistry instructional materials used in the schools as reported by the students (see Table 5.23). According to the participants, TV instruction has some most helpful features in learning chemistry. Some of these most helpful natures were the emphasis it gave for diagrammatic and atomic representations, textual and verbal explanations, and mathematical forms of presentations. Plasma TV instruction also helped them to observe chemical changes and occurrences which happened during chemical reactions. Some of the participants' views on most helpful nature of TV instruction are presented as follows.

233PEH: Plasma TV instruction presents diagrammatically and symbolically. It is good for symbolic representation, and practical work.

266PEL: I prefer plasma TV instruction. Because it gives more emphasis to diagrammatical representations, models, molecular formula and structural representations.

325PEH: The TV instruction & diagrammatical presentations are very useful to understand well. Practical activities (education) and TV instruction are unique in that they are important in attracting students' attention and motivating so as to learn/understand chemistry better.

294PEL: The TV instruction is very much useful to good performance and acquires knowledge. TV instruction is better and presents via diagrammatic and symbolic representations, practical activities/work, and model. Diagrammatic presentations and plasma instructions contributed relatively better to my performance.

35PEM: The TV instruction can provide adequate understanding to me on different mathematical expressions and different laboratory works. TV instructions give more emphasis on symbolic and molecular representations.

36PEL: The plasma TV instruction that explains chemistry in terms of diagrams, atomic representations and laboratory works helps to grasp the main points.

37PEM: Plasma TV instruction explains well the activities in student's chemistry text book and presents with detail and quality.

The most helpful nature of student's chemistry Textbook

Student's chemistry text book was another most helpful instructional material which contributed to students' academic performance in chemistry (see Table 5.23). Participants responded that among the most commonly used instructional materials which were experienced by students in both preparatory schools was student's chemistry textbook. They described that some of the most helpful features of the textbook were that it provides details and adequate explanations to chemical concepts and theories in a clear language and colored format. It also presents chemical concepts in the form of diagrammatic, mathematical and atomic representations, molecular and structural formulas and models along with different textual explanations which made the text book suitable and understandable to students. Some of their full responses to the question were:

37PEM: Practical work and student's chemistry text book mainly focused on diagrams, atomic representations and models. Therefore as to me this has a great advantage to me. For instance, periodic table explains the characteristics of elements which play a great role in chemistry. Student's chemistry text book preparation and use of teaching aid by the teacher has great contributions.

57PEH: Student's chemistry text book explanation in the form of theory, mathematical expression, diagrammatic representation and practical works.

325PEH: Next to the plasma student's chemistry textbook clearly presents in a colored format. Student's chemistry textbook provides more emphasis to theoretical explanations.

287PEH: Student's text book comprehensively presents than the class room teacher. As student's chemistry textbook is colored and presented in a clear language I prefer to use it than using other materials.

311PEL: Student's text book well presents chemical concepts and theories.

233PEH: Student's chemistry textbook helps to understand chemical concepts in the text book

222PEH: Student's chemistry textbook is laboratory focused. Therefore laboratory based instruction is good to me.

The most helpful nature of practical work

The participants of this study responded that they were exposed to learning laboratory. Based on their experiences therefore, they stated some of the most helpful features of practical work which boosted their academic performance. The most helpful features of practical work boosted, which students' academic performance by helping them to prove theories taught in classes, supporting them to understand chemical concepts and theories and by being a base for long lasting base of chemistry learning. A sample of participants' description about the features of laboratory work is presented as follows.

266PEL: Laboratory work, because it helps to observe the chemical changes and occurrences and is very helpful.

222PEH: Practical activities/work and teaching aid by teacher are relatively more productive than others. Because laboratory based clearing are long lasting and the base for chemistry learning. Laboratory work helps to realize (prove) what has been taught theoretically in the classroom. Therefore, we can be easily convinced. As a result practical work can be useful to understand chemistry. Student's chemistry textbook is laboratory focused. Therefore laboratory based instruction is good to me.

155PEH: From the materials I have listed above, laboratory work is more helpful/useful to me prove what I have learned theoretically in the laboratory.

266PEL: Practical work is very important to remember what has been learned through practical work. Practical/laboratory work helps to relate theory and practice.

36PEL: Practical work helped me more.

37PEM: Adequate books and teaching supported by practical activities has great contributions.

267PEL: Teaching aid by the teacher and practical work has good contribution to my performance. Because when what the teacher taught and told in the class supported by practical works, it could be clear and understandable.

311PEL: Practical activities/works are good to remember the school.

325PEH: Practical work based instruction was important to me not to forget.

The most helpful nature of teaching aids and utilization by teachers

Teaching aids prepared by classroom chemistry teachers were commonly used instructional materials by students in both schools (see Table 5.23). According to participants of this study, some of the most helpful features of the teaching aids were that, they presented learning experiences in terms of molecular formulas and structures, and pictorial presentations of chemistry. Learning resulted from teaching aids supported instruction was long lasting. Moreover, they described that teaching aids could identify their learning difficulty of chemical concepts and theories and fill learning gaps and accompanied by teacher's oral and textual explanations. Some of the most recurring views about the most helpful features of teaching aids are presented as follows.

267PEL: from the list of materials given above, the teaching aids by the teacher give more emphasis to textual and oral explanations. Because while the teacher is teaching it is possible to teach what is remain to be unclear. Teaching aid by the teacher is very important because the teacher can orally explain and show using aids.

233PEH: As the teaching aid by the teacher emphasized diagram and mathematical representations, it is very much useful. For example, Plasma TV instruction emphasize for symbolic representation, practical work. In general all of them are useful but I guess the teaching aid is more useful than others.

106PEL: Teaching aid by teachers which give more emphasis to mathematical, atomic, and molecular representation are more useful to practical activities. 1 to 5 group discussion with other students is very good to me.

35PEM: Teaching aids by teachers give more emphasis to atomic representation, molecular formula and structure.

36PEL: Teacher's teaching and my attentiveness to the teachers teaching and asking questions to my teachers contributed to my current result.

325PEH: The teacher's classroom presentation/lecture can help to make it clearer what has been presented in the text book. It is because teaching aid can help to improve the quality of education.

311PEL: Teaching aid by the teacher also helps to fill the gap by identifying students' weaknesses and strengths. Teaching aid by the teacher, student's chemistry text book and practical work helped me in leaning chemistry. Student-student interaction; and student-teacher interaction in and out of class were helpful to share knowledge or information. Moreover, working on sheets contributes to my performance.

294PEL: Teaching aid by the teacher is the most useful. My current performance mainly resulted from attending my teachers' classroom instruction, discussion with my friends, and group study. Particularly studying and working with my friends helped me very much.

The least helpful characteristics of instructional materials in the schools

Participants were also asked to list and describe the nature of chemistry instructional materials which contributed least to their academic performance in chemistry. The questions asked to them were:

Question 5: From the chemistry instructional materials (i.e. your textbook, television instruction, practical/laboratory activities and teaching aids) in use by your school;

A. Please list chemistry instructional materials which relatively you consider least helpful to your current performance in chemistry in their order of importance?

B. Please describe the characteristics of chemistry instructional material(s) you have listed under "5A", with regard to its/their relative emphasis to diagrammatic, symbolic, molecular formulas and structures, and models, mathematical presentations?

C. Please describe the characteristics of chemistry instructional materials you have listed above in "5A", with regard to the relative emphasis to textual and oral presentations?

D. Please mention any characteristics of chemistry instructional materials that you consider least helpful to your current performance in chemistry, if not mentioned yet?

Question 6: What do you recommend to re-prepare the chemistry instructional materials in such a way that can help you to perform better in chemistry?

In response to these questions, participants described some of the least helpful characteristics/nature of the most common chemistry instructional materials used in the schools. Detail descriptions of the least helpful nature of each of these instructional materials are presented independently in the following separate sections.

The least helpful nature of Plasma TV based chemistry instruction

Although Plasma TV chemistry instruction provided variety forms of learning experiences to learn chemical concepts, particularly extremely low performing students suggested that it also has least helpful features. Some of these features which made students not to be successful in learning chemical concepts were described by the participants. These features were that, Plasma TV instruction was not well delivered, difficult to understand and ask questions, very fast and brief and difficult to pay attention which could lead to confusion and failure to understand chemical concepts and theories. Some of the participants' full descriptions about the less helpful features of plasma TV chemistry instruction were:

266PEL: Although plasma instruction has some advantage, it is difficult to catch up or pause and ask what is unclear and left unheard. Therefore this may leave students get confused. Plasma instruction in my opinion is better to be replaced or if not the time given for it has to be increased, so that we can learn and perform better. Because the 20 minutes allotted time for the TV instruction currently does not bring learning but confusion and disturbance.

267PEL: From the list of instructional, materials plasma instruction has contribution to my reduce performance. Because, the TV lesson does not go along with student's chemistry textbook and teachers lecture. Therefore, it has poor contribution to me. Plasma TV instruction has least contribution to my performance. Because as it is very fast and brief it is difficult to catch and understand what the TV teacher teaches. Plasma TV presents everything important, but I cannot understand everything what has been presented and its presentation is brief and short. It does not address all diverse groups of classroom students as the classroom teacher does.

222PEH: Plasma instruction has little contribution to my semester result. Because the plasma teacher simply reads what is there in the text book, as a result it killed my time. It kills my time that I could use to ask my teacher that could help me to understand.

311PEL: Plasma instruction hasn't any worthy/significant contribution to my performance. Rather it killed the time that the teacher could use it for teaching. Therefore plasma instruction has bad/ negative contribution to my performance.

287PEH: The plasma TV presentation is brief and fast therefore the student's chemistry text book is better than it.

57PEH: Plasma TV instruction, because it is very fast and difficult to capture. Therefore, there are many things which are covered while I did not able to understand them. TV instruction gives more emphasis but as it is fast, it is difficult to understand. Plasma TV instruction is very fast and difficult to give attention.

106PEL: Plasma education is very good. However, as the subject is difficult and it is would be better if it is taught by the classroom teacher. Because you can ask the teacher if you face difficulty but this opportunity is absent for the plasma instruction. Plasma TV instruction is not well delivered. Moreover the plasma instruction is not clear to understand. However, when the teacher teaches you can be better and can ask your teacher. But all these things are impossible in the case of plasma instruction.

The least helpful nature of student's chemistry Textbook

Participants were reserved to mention the least helpful features in the same way as they did for Plasma TV based chemistry instruction. However, the only drawback which affected students' academic performance in chemistry was the emphasis it gave to textual explanations over practical works. Some participants explained the less helpful natures of the textbook as follows:

267PEL: Student's chemistry textbook tries to present textually and diagrammatically. However, it is difficult to understand fully from the diagram only. It is because, what has been presented diagrammatically in the text book may be completely new to the learner.

233PEL: Student's chemistry textbook; Practical activities/work; Plasma TV instruction; and teaching aid by the teacher. Because, students who couldn't learn by reading independently, they can learn from the practical work, plasma instruction, and teaching aid by the teacher. Therefore student's chemistry text book has little contribution to my performance.

The least helpful natures of practical work

Views from the participants showed that least helpful feature of practical was not attributed to its intrinsic behavior rather it is related to the extent of exposure to practical work. They complained that chemistry practical work was not as helpful as it had to be because of less exposure for practical work. Students argued that practical works were not most helpful not because of its intrinsic nature rather by inadequate arrangement and less attention for practical work in both schools. Limited practical work, limited mathematical representations, and lack of prior experiences of practical work affected the helpful natures of practical work. Some of the participants' critics on practical work were as follows.

297PEH: Practical work has little contribution to my performance. It is because we work practical activities once per semester or three months. As a result teaching by laboratory work is not satisfactory to me. I said this because of the schools lack of attention to practical work and my background was limited to teaching that focused on teaching theories.

287PEH: Limited practical works and mathematical works contributed to the reduction of my result. Inattentiveness (lack of focus) to questions also affected my result negatively.

37PEM: Student's chemistry text book preparation and use of teaching aid by the teacher has great contributions. Because learning from practical work cannot be easily remembered.

36PEL: *Teaching aid by teachers contributed little to me. Because they give little/limited explanations and lacks practicality and they are vague to understand.*

In sum, the analyses on the data about the nature of the common chemistry instructional materials used in both schools showed that, the instructional materials were different and provide various forms of presentations. These chemistry instructional materials were more accommodative to different learning styles. Every single chemistry topics were taught using different instructions. If a learner was disadvantaged by the forms of presentations of one of the chemistry instructional materials, he/she was supported by other forms of presentations in the other chemistry instructional materials. Therefore, students in both schools had enjoyed nearly similar opportunity of learning experiences. In other words, students were not disadvantaged in both schools because of being different in their learning styles. Of course, unless there might be a particular chemical concept and chemistry specific learning style existed, difference in academic performance on the fundamental chemical concepts under investigation was not expected to be observed.

The qualitative phase of the study revealed that students' difference in academic performance in chemistry was not associated with their instructional material preferences. The study finds out that students with the same learning styles/preference and who used the same instructional material performed extremely different.

5.8.3. Summary

Concerning the nature of chemistry instructional materials used in both schools, there were different types of chemistry instructional materials. In both schools, any single chemistry topic was taught using at least two instructional materials such as, student's chemistry textbook and Plasma TV instructions. On top of these practical activities, teaching aids, group works, and teachers' presentations provided more learning opportunity to students with different learning styles. These variety forms of instructional presentations were suitable to reach to students with different learning styles. Therefore, the roles of chemistry instructional materials used in both schools were expected to have similar impacts on students' academic performance on the fundamental chemical concepts considered under this investigation. Because, the variety of instructional materials used in the schools were able to cater students with different learning styles. As a consequence, differences in academic performance were not expected to be caused by marginalization of students by their learning styles but other instructional variables.

A comparison was made to see if students' preference to the nature of these instructional materials had some meaningful patterns with their academic performance on the fundamental chemical concepts under investigation. The result revealed that students' preferences to the nature of chemistry instructional materials were not linked to their level of academic performances measures on some fundamental concepts in chemistry. Because, there were some students who had the same instructional preferences, but some of them performed extremely high and others performed extremely low. On the contrary, there were some students with different instructional preferences but some of them performed extremely high and others performed extremely low. The study also revealed that, those students with the same learning style combinations and same instructional preference performed extremely differently (i.e. some performed extremely high and some performed extremely low).

In sum, from the descriptions given by students performing extremely low (PEL), students' performing extremely high (PEH) and students with the same learning style combinations about the nature of chemistry instructional materials used in the schools and their influences on their academic performance, I have learned that the match or mismatch of learning styles to instructional materials were not sources of differences in their academic performances differences on the tests constructed from some fundamental concepts in chemistry. Moreover, different forms of instructional materials were used in both schools provided different learning opportunity for students with different learning styles. Therefore, students' differences in academic performance under different learning opportunities in both schools might be attributed to other instructional variables than to learning styles.

Chapter 6 Summary, conclusions, limitations and recommendations

6.1. Summary

In the quantitative phase of this study, the regression analysis revealed that variation in Felder-Silverman learning styles failed to provide statistically significant explanation to variations observed in student's academic performance on the tests constructed from some fundamental concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms between. In other words, the regression model fit test for grade levels presented in Tables 5.9; 5.10; 5.11; and 5.12 showed that the proportion of prediction (R square) of academic performance in chemistry was very small and it was not statistically significant. Therefore, the proportion of variation in students' academic performance on some fundamental concepts in chemistry that could be explained by variations in Felder-Silverman learning styles was very small and it was not statistically significant.

The independent sample t-test and correlation coefficients presented in Tables 5.5 to 5.6 and in Tables 5.13 to 5.20 also showed that there was not a particular type of learning styles which helped science students to excel in academic performance on some fundamental concepts in the topics investigated. It means that, no statistically significant difference was observed in academic performance on some fundamental concepts in chemistry that could be accounted for the differences in learning styles. Being Sensing or Intuitive, Visual or Verbal, Active or Reflective, and Sequential or Global learner didn't to lead to statistically significant difference in academic performance on the fundamental chemical concepts considered under this investigation.

In general in the quantitative phase of the study, no statistically significant pattern of systematic variation was observed in academic performance on some fundamental concepts in chemistry linked to systematic variations in learning styles. This finding was further verified by examining the academic performances of science students with the same learning style combinations (see Table 5.4) on the tests constructed from the fundamental concepts in chemistry. The examination revealed that there were some science students who had the same learning style combination but who performed extremely different on the tests. It means that regardless of having the same learning styles combinations, 1) there were students who had extremely high academic performance on the test and, 2) there were students who had extremely low academic performance on the tests.

To buttress the quantitative phase of the study, the qualitative study was conducted to explore why some learners with the same or different learning style combinations and taught under the same instructional context performed extremely different on the tests constructed from some fundamental concepts in chemistry. The participants of the qualitative phase of the study were selected from some extreme cases (i.e. students performing extremely different) of the quantitative phase of the study. Then, students' academic performance on some fundamental concepts in chemistry was explained through chemistry instructional materials used in the schools.

Participants in the qualitative phase of this study reported that chemistry instructional materials used in the schools, such as TV instruction and student's chemistry text book were among the most common and standardized chemistry instructional materials used in both preparatory schools. Practical work, teaching aids, teachers' presentation, and group work were among the influential chemistry instructional materials used in both preparatory schools.

Participants of the qualitative this study described the characteristics of these chemistry instructional materials and their influence on students' academic performance on some fundamental concepts in chemistry. Their description indicates that chemical concepts considered in this study were taught through different chemistry instructional materials which could offer an opportunity to learn for students with different learning styles. Consequently, it was less probable to expect a disadvantaged student because of his/her difference in learning styles combinations. If no learners were marginalized by chemistry instructional materials used in the schools due to learning styles difference, no statistically significance performance difference would be anticipated that could be accounted for difference in learning style, unless there was a chemistry specific leaning styles. Moreover, there were students who had the same instructional preference and who had been taught in the same instructional context, but they performed extremely different on the same test.

6.2. Conclusion

The result of the quantitative phase of this study showed that academic performance on some fundamental chemical concepts in the topics: Atomic structure and periodic table, and chemical bonding and structure, acid-base equilibrium and common thermodynamic terms was not the function of Felder-Silverman learning styles. This implies that learning styles preferences did not have statistically significant direct influence on preparatory science students' academic performance in the fundamental chemical concepts under investigation. Thus, the researcher concludes that students' learning styles preferences was not the source of academic performance on the fundamental chemical concepts considered under investigation.

Regression model fit test also reveals that Felder-Silverman learning styles dimensions total explanatory or predicting power of students' academic performance on the fundamental chemical concepts under investigation was extremely small and statistically not significant. This suggests that there might be other important instructional variables which could explain academic performance than learning styles could do. Particularly the representational nature of chemistry is an important instructional variable to consider. Therefore, instructional decisions in the teaching–learning process of these chemical concepts through instructional materials and teaching methods has to be designed mainly based on the nature of the chemical concepts and then to accommodate different learning style preferences.

There is no one best learning style or one best teaching style, matching learning styles to teaching styles needs weighing the advantage and disadvantage of both learning styles and teaching styles (Kapadia, 2008). As already stated by Treagust and Chittleborough (2001), learning chemistry is a matter of understanding representations of chemistry. Therefore, as the nature of chemical concepts demand their own ways of representations, weighing the advantage and disadvantage of teaching styles or selection of chemistry instructional materials needs to give more weight to the nature of chemical concepts and ways of its representation than to learning styles.

The qualitative phase of this study also shows that the instructional materials used in both schools have various forms of presentations. These various forms of chemistry instructional materials were designed based on the nature of chemical concepts and caters for different learning styles. Therefore, these multiple forms of instructional presentations can improve students' academic performance in chemistry.

Scholars in the field of learning styles such as Dubetz, et al. (2008), Honigsfeld and Schiering (2004), and Timothy and Kimberly (2010) argue that multiple instructional strategies are important to reach individual students with different learning styles. Accordingly, expected marginalization of students due to leaning style differences might be canceled by the teaching of chemical concepts through variety forms of chemistry instructional materials used in both schools. It might be for this reason that differences observed in students' academic performance failed to be statistically significantly linked to learning style differences. Hence, whenever, the representational nature of chemistry allows you to present in different forms, it would be helpful to reach students with different learning styles. From the qualitative part of the study, I have also learned that the same learning style and instructional preference failed to lead towards similar performance tendency.

In sum, from the findings of both the qualitative and quantitative phase of the study the researcher conclude that there wasn't any superior learning style that helped students' academic performance on the fundamental chemical concepts considered in this study.

6.3 Limitation of the study

This study was conducted on some fundamental chemical concepts in the topics: Atomic structure & periodic table, Chemical bonding and structure, Acid-base equilibrium and common Thermodynamic terms. Therefore, generalizing the findings of the study should be limited to the fundamental chemical concepts considered under this investigation and under similar instructional context described in the qualitative phase of this study. Hence, generalizing the finding of this study to other chemical concepts, theories, scientific skills in laboratory works and other areas of chemistry might lead to ecological fallacy. Therefore, care has to be taken to consume the findings of this study for instructional decisions on other chemical concepts.

The study was conducted in two preparatory schools in Ethiopia. In these schools chemistry was taught using nationally prepared textbooks, plasma TV guide, teacher's guide, nationally broadcasted plasma TV based chemistry instruction and other school based instructional resources. These instructional contexts were able to address different learning styles. Therefore, the findings of this study might not be workable to other instructional settings where some students are marginalized.

Although this study used a mixed sequential design, the quantitative phase of the study was cross sectional study. The finding that shows the small and non significant proportion of prediction of academic performance from Felder-Silverman learning styles might be mediated by other variables, and therefore unless this study is repeated in a similar and different context to consume the findings may lead to naïve conclusion.

6.4 Recommendations

The quantitative phase of the study showed that learning styles are not statistically significant predictors of Academic performance. Hence, in making different instructional decisions in teaching the fundamental concepts considered in this study, instructional designers and teachers should give priority to the nature of the chemical concepts and then to learning styles.

In some instances, when teachers or instructional designers represent a chemical concept in pedagogical representations that only match with learning styles but not with the scientific representations of the chemical concept, it may cause students to develop a misconception. Therefore, pedagogical representations of chemistry should give more priority to match with the scientific representational nature of chemistry.

From the qualitative part of the study, the researcher has learned that chemistry was taught using different instructional technologies. These different forms of instructional materials were more accommodative to students with different learning styles. Therefore, as far as the representational nature of chemistry is amenable to different forms of presentations, instructional designers should use different formats of instructional materials in the ways that can benefit the majority of students.

The study also noted that there is scarce of chemistry education models that integrate the nature of chemistry and learners characteristic ways of learning. Therefore, to introduce a comprehensive chemistry education model that integrates learning styles and existing chemical education models and that expand the pedagogical content knowledge in chemistry; this study has to be replicated by chemical education researchers:

- in a similar setting and different other settings in and/or outside of Ethiopia
- on fundamental chemical concepts considered under this study,
- and on other chemical concepts and areas of chemistry

Moreover, further study on the role of learning styles on academic performance in other science, such as biology, mathematics and physics also needs to be conducted. A further study on how to integrate learning style into science education is important to introduce learning styles model that suits with the nature of these science disciplines.

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Appendices

Appendix A: Fundamental concepts covered in grade 11 and 12 chemistry syllabi

Table 1. Fundamental chemical concepts covered in first semester of the 11 & 12 chemistry syllabus

S.No	Fundamental concepts of chemistry , Schummer (2003, 2006) & Caldin (2002)	Grade 11 (Syllabus)	Grade 12(Syllabus)
1	Element	Unit-2. Atomic structure and periodic table	Unit-5. Some elements in nature and industry
2	Pure substance		
3	Chemical species		
4	Compound		
5	Affinity	Unit-2. Atomic structure and periodic table	
6	Chemical reaction	Unit-3. Chemical bonding and structure	Unit-2. Acid-base equilibrium Unit-3.Introduction to thermodynamics Unit-4. Electrochemistry
7	Atom and subatomic particles	Unit-2. Atomic structure and periodic table	
8	Molecules & molecular structure	Unit-3. Chemical bonding and structure	
9	Practical method (experimentation)		
10	Energy	Unit-4. Chemical kinetics	Unit-3.Introduction to thermodynamics
11	Cognitive method of chemistry: A. Pictorial language of chemistry B. Model building & representation	Unit-2. Atomic structure and periodic table Unit-3. Chemical bonding and structure	
12	Chemical theories	Unit-2. Atomic structure and periodic table Unit-3. Chemical bonding and structure Unit-4. Chemical kinetics	Unit-2. Acid-base equilibrium

Table 2. Tables of specification for tests on fundamental chemical concepts in grade 11 semester-I syllabus

Unit & total period assigned to	Sub-units	Periods assigned for a	Expected number of items per sub-unit	Actual number of number of Items used per sub-unit	Remark
Unit-2. Atomic structure & periodic table Subunits of the unit (28 periods)	2.1. Historical development of the atomic nature of substance	1	-		
	2.2. Dalton's atomic theory and modern atomic theory: o Postulates of Daltons atomic theory o How the theory explains mass laws	2	1	Q_1	
	2.3. Early experiments to characterize the atom: o Discover of the electron o Discover of the nucleus o Discover of the neutron	3	1	Q_7	
	2.4. Makeup of the nucleus: o Constituents of the nucleus o Atomic mass & isotopes	2	1	Q_{12}	
	2.5. Electromagnetic radiation(EMR) & atomic spectra: o The quantum theory & photon o Atomic spectra o The Bohr model of the hydrogen atom o The limitation of the Bohr theory	9	4	$Q_{2,15,16,18}$	
	2.6. The quantum mechanical model of the atom: o The Heinsenberg's principle o Quantum numbers o Shape of atomic orbital	5	2	$Q_{3,13,20}$	
	2.7. Electronic configuration & orbital diagrams: o Aufbau principle, Pauli exclusion principle & Hund's rule o Ground state electronic configuration of the elements	2	1	$Q_{19,21}$	
	2.8. electronic configuration & the periodic table of the elements: o The modern periodic table o Classification of the elements	4	2	$Q_{3,9,17}$	

	o Periodic properties o Advantage of periodic table				
Unit- Chemical bonding and structure (total 32 periods)	3.1. Introduction: o Octet rule o Types of chemical bonding	1	-		
	3.2. Ionic Bonding: o Lewis dot electron dot symbols o Formation of ionic bonding: the Born Haber cycle & factors affection ionic bond formation o Exceptions to octet rule o Properties of ionic compounds	5	2	$Q_{4,11}$	
	3.3. Covalent bonding: o Formation of covalent bonding o Representation of covalent bond: draw Lewis structure o Coordinate covalent bond o Resonance structures o Exception to the octet rule o Polar & non-polar covalent molecules o Properties of covalent compounds	15	6	$Q_{4,5,6,8,10,11}$	
	3.3.1. Molecular geometry: o Valence shell electron pair (VSEPR) theory o Electron pair arrangement & molecular shape o Guideline for applying VSEPR model o Molecular shape and molecular polarity: bond polarity, bond angle & dipole moment o Predicting the shape of molecules				
	3.3.2. Intermolecular forces in covalent compounds: o Dipole-dipole force o Hydrogen bonding o Dispersion or London force				
	3.4. Metallic bonding: o Formation of metallic bond & electron see model o Properties of metals related to the concept of bonding	2	1	Q_{14}	

	3.5. Chemical bonding theories	8			Not covered in the first semester
	3.5.1. Valence bond theory (VBT): ○ Overlap of atomic orbital & hybridization ○ Sigma & pi bonds				
	3.5.2. molecular orbital theory: ○ Combination of atomic orbitals ○ Bonding & antibonding molecular orbitals ○ Electronic configuration of diatomic molecules ○ Bond order ○ Magnetic properties				
	3.6. Types of crystals: ○ Ionic crystal ○ Molecular crystal ○ Covalent network crystal ○ Metallic crystal	1			Not covered in the first semester

NB. The total proportion of number of items are decided based on the total proportion of number of periods assigned to each subunit and the fundamental concepts of chemistry treated under each subunit. If a particular subunit doesn't treat fundamental chemical concepts, items are not designed for that specific subunit. That is:

$$\text{total number of items per topic} = \frac{\text{number of items in the test x periods allotted for the topic}}{\text{the total number of periods for topics in which the test is constructed}}$$

Table 3. Tables of specification for tests on fundamental chemical concepts for grade 12, semester-I chemistry syllabus

Unit & total period assigned to each	Sub-units	Periods assigned for each sub-unit	Expected number of items per sub-unit	Actual number of number of Items used per sub-unit	Remark
Unit-2. Acid-base equilibrium (26 periods)	2.1. Acid-base concepts: o Arrhenius concepts of acids & bases o Bronsted-Lowry acids-bases: Conjugate acid-base pair, auto ionization of substances, & amphiprotic species o Lewis concept of acids and bases	5	4	$Q_{1,2,3,7,12}$	
	2.2. Ionic equilibrium of weak acids and bases: o Ionization of water: ion product for water, K_w o Measures of strength of acids & bases: - H^+ ion concentration, $[H^+]$, p^H - OH^- ion concentration, $[OH^-]$, p^{OH} - Percent ionization - Ionization/dissociation constant - Base ionization constant (k_b), acid ionization constant (k_a)	9	7	$Q_{1,3,6,10,11,20,22}$	
	2.3. Common ion effect & buffer solution: o Common ion effect o Buffer solutions	4	3	$Q_{13,15,21}$	
	2.4. Hydrolysis of salts: o Salts of weak acid & strong bases: anion hydrolysis o Salts of strong acid & weak bases: cation ion hydrolysis o Salts of weak acid & weak bases: cation & anion hydrolysis	2	2	$Q_{19,21}$	
	2.5. Acid base indicators & titrations: o Acid-base indicators o Equivalents of acids &bases : Number of equivalents & normality o Acid-base titration o The equivalent point & end point o Acid-base titration curves: - titration of strong acid with strong bases, - titration using weak acid & strong bases, - titration using weak bases & strong acid,	6	5	$Q_{4,5,8,9,,20}$	

Unit-3. Introduction to chemical thermodynamics (12 periods)	3.1. Common Thermodynamic terms: system, surroundings, functions, properties & process, isothermal, adiabatic, state, equation of state, heat capacity, specific heat, state function, state variable, path function	2	2	$Q_{16,17,18}$	
	3.2. First Law of Thermodynamics & some thermodynamic quantities: o Internal energy (E) o Heat (q) o Work (w) o First law of thermodynamics	3			Not covered by first semester
	3.3. Thermo chemistry: o Heat of reaction (enthalpy energies) o Standard states o Hess's law o Bond energies	4			Not covered by first semester
	3.4. Entropic and Second Law of Thermodynamics: o Entropies and spontaneous process o Second law of thermodynamics o Free energy o Criteria for spontaneous process (ΔS, ΔG, ΔH)	3			Not covered by first semester

NB. The total proportion of number of items are decided based on the total proportion of number of periods assigned to each subunit and the fundamental concepts of chemistry treated under each subunit. If a particular subunit doesn't treat fundamental chemical concepts, items are not designed for that specific subunit

Appendix B: Semi-structured and open ended-questionnaire for students about chemistry instructional materials

Section I. English versions of the Questionnaires

Grade level: ____________

Code/S. NO: ____________

The aim of this questionnaire is to describe the type and nature of chemistry instructional materials in your school which highly influences your chemistry performance. There are 6 items in this questionnaire pertaining to the type and nature of instructional materials in use for chemistry lessons. They are statements to be considered in the context of the chemistry lessons in which you have learned in the current semester.

Therefore for each question 1-3, choose & circle only one answers **(i.e. "a" or "b")** and provide your reason of choice. But, **for questions 4-6, list down** chemistry instructional materials as per the requested **under "a"** and then explain the nature of each of your list under **"a"** as per the request **under "b".** The questionnaire may take 20 minutes to complete.

Your answers will help me to understand what I can be doing better to help you in your chemistry learning. Thank you for completing the questions.

Instruction I: For each question **1-3** below, choose & circle only one answers **(i.e. "a" or "b")** and provide your reason of choice.

1. The characteristics of instructional materials which determine my current performance in chemistry is/are explained by its/their emphasis given to :
   A. diagrammatic, symbolic, molecular & structural formula, model and mathematical representations of chemistry.
   B. textual explanations /words presentation of chemistry

   Provide reason for your choice,

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2. The characteristics of instructional materials which determine my current performance in chemistry is/are explained by its/their emphasis given to:
   A. practical activities
   B. conceptual and theoretical explanation of chemistry

   Provide reason for your choice,

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3. The characteristics of instructional materials which determine my current performance in chemistry is/are explained by its/their emphasis given to:
   A. Chemical concepts and theories through mathematical relations or representations in a summarized manner.
   B. the details of chemical concepts and theories through oral or textual presentation

   Provide reasons for your choice,

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   _____________________________________.

Instruction II: For questions **4-6** below, list down the chemistry instructional materials as per the requested under **"a"** and then explain the nature of each of your list under **"a"** as per the request under **"b".**

4. From the chemistry instructional materials (i.e. your textbook, television instruction, practical/laboratory activities and teaching aids) in use by your school;
   A. Please list chemistry instructional materials you consider most helpful to your current performance in chemistry in their order of importance?

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      ____.

B. Please describe the characteristics of chemistry instructional materials you listed under "4A", with regard to their emphasis to diagrammatic, symbolic, molecular structures & formulas, models and mathematical presentations?

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C. Please describe the characteristics of chemistry instructional material(s) you listed under "4A", with regard to it/their emphasis to textual and oral presentations?

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D. Please mention any essential characteristics of chemistry instructional materials that you consider most helpful to your current performance in chemistry, if not mentioned yet?

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5. From the chemistry instructional materials (i.e. your textbook, television instruction, practical/laboratory activities and teaching aids) in use by your school;

A. Please list chemistry instructional materials which relatively you consider least helpful to your current performance in chemistry in their order of importance?

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____.

B. Please describe the characteristics of chemistry instructional material(s) you have listed under “5A”, with regard to its/their relative emphasis to diagrammatic, symbolic, molecular formulas and structures, and models, mathematical presentations?

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C. Please describe the characteristics of chemistry instructional materials you have listed above in “5A”, with regard to the relative emphasis to textual and oral presentations?

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D. Please mention any characteristics of chemistry instructional materials that you consider least helpful to your current performance in chemistry, if not mentioned yet?

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6. What do you recommend to re-prepare the chemistry instructional materials in such a way that can help you to perform better in chemistry?

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____.

Section II. Amharic versions of the Questionnaires

ክፍል አንድ፤ የተማሪዎች መጠይቅ

የክፍል ደረጃዎትን፣ሴክሽን እና መለያ ቁጥርዎትን በተጠየቀዉ መሰረት በተሰጠዉ ባዶ ቦታ ይፃፉ።

የክፍል ደረጃ እና ሴክሽን፡__________________________

መለያ ቁጥር፡__________________________

ይህ ጥናት የሚካሄደዉለዶክትሬት ዲግሪ መመረቂያነት ነዉ። የጥናቱ አላማም፤

1ኛ) ተማሪዎች በሚመረጡት የመማሪያ መንገድና በከሚስትሪ ትምህርት በሚያስመዘግቡት ዉጤት መካከል ያለዉን ዝምድና መለየት

2ኛ) ተማሪዎች የሚያስመዘግቡትን የኬሚስትሪ ዉጤት ከሚጠቀሙት የመርጃ/መማሪያ መሳሪያ(ዎች) ጋር ያለዉን ዝምድና እንዴት እንደሚገልጹት ለመረዳት ነዉ። የዚህ ጥናት ዉጤትም ተማሪዎች በኬሚስትሪ ትምህርት የተሻለ ተጠቃሚየሚሆኑበትን መንገድ ሊጠቀም ይችላል።

በመሆኑም የዚህ መጠይቅ አላማዉ ተማሪዉ/ዋ በኬሚስትሪ ትምህርት በአንፃራዊነት ጥሩ የመማር ዕድል የፈጠሩለ/ላ/ትን የኬሚስትሪ ትምህርት መርጃ (መማሪያ)መሳሪያ(ዎች) አይነትና ባህሪይን ለማወቅ ነዉ። መጠይቁም ይህን ለማወቅ የሚረዱ 6 ጥያቄዎችን ይዟል። ከ 1 እስከ 3 ላሉት ለእያንዳንዱ ጥያቄ አንድ መልስ ብቻ (ምርጫ “ሀ”ን ወይም “ለ”ን) በመምረጥ እና በመከበብ ምክንያትዎን ያብራሩ። ከ 4 እስከ 6 ላሉት ለእያንዳንዱ ጥያቄ ደግሞ በፊደል ተራ “ሀ” ስር በመዘርዘር፣ በፊደል ተራ “ለ” ስር በተጠየቁት መሰረት ማብራሪያ ይስጡ። መጠይቁን ለመሙላት 20 ደቂቃ ገደማ ሊዎስድብዎት ይችላል። በዚህ ጥናት ተሳታፊ በመሆንዎና ጥያቄዎቹን ሙሉ በሙሉ ሰርተዉ በመመለስዎ ምስጋናዬ ከወዲሁ እጅግ ላቅ ያለ ነዉ።

ትዕዛዝ አንድ፤

ከ 1 እስከ 3 ላሉት ለእያንዳንዱ ጥያቄ አንድ መልስ ብቻ (ምርጫ“ሀ”ን ወይም “ለ”ን) በመምረጥ እና በመከበብ መልሰዎትን ያሳዩና ምክንያትዎን ያብራሩ።

1. ከተማርኩባቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች መካከል አሁን በኬሚስትሪ ያገኘሁትን ዉጤት በይበልጥ የወሰኑት የመርጃ መሳሪያዉ መገለጫ ባህሪያት ፡-

ሀ/ ኬሚስትሪን በይበልጥ በዲያግራም (diagram)፣ በአቶም ወካይ (symbol)፣ በሞዴል (model)፣ በሞለኪዩል መዋቅርና ቀመር (molecular structure and fomula) እና በስሌታዊ አገላለጽ (mathematical representation) ማቅረቡ ነዉ።

ለ/ ኬሚስትሪን በይበልጥ በፅሁፍና በድምፅ አብራርቶ ማቅረቡ ነዉ።

ሐ/ ሌላ የበለጠ መገለጫባህርያት አሉት።

ለመረጡት መልስ ምክንያትዎ ቢያብራሩ፥ ____

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2. ከተማርኩባቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች መካከል አሁን በኬሚስትሪ ያገኘሁትን ዉጤት በይበልጥ የወሰኑት የመርጃ መሳሪያዉ መገለጫባህሪያት ፡-

ሀ/ ኬሚስትሪን ተግባር ተኮር (practical activities) ትምህርት አድርጎ ማቅረቡ ነዉ።

ለ/ የኬሚስትሪን ፅንሰ ሀሳብ (concept) እና ንድፈ ሃሳብ (theory) አብራርቶ ማቅረቡ ነዉ።

ሐ/ ሌላ የበለጠ መገለጫባህርያት አሉት።

ለመረጡት መልስ ምክንያትዎን ቢያብራሩ፥ ____-

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3. ከተማርኩባቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች መካከል አሁን በኬሚስትሪ ያገኘሁትን ዉጤት በይበልጥ የወሰኑት የመርጃ መሳሪያዉ መገለጫባህሪያት :-

ሀ/ የትምህርቱን ፅንሰ ሀሳብና ንድፈ ሃሳብን በስሌታዊ አገላለጽ (mathematical represenation) ጠቅለል አድርጎ ማቅረቡነዉ።

ለ/ የትምህርቱን ፅንሰ ሀሳብ እና ንድፈ ሃሳብ በንግግርና በፅሁፍ ዘርዘር አድርጎ ማቅረቡነዉ።

ሐ/ ሌላ የበለጠ መገለጫባህርያት አሉት።

ለመረጡትመልስ ምክንያትዎን ቢያብራሩ ____

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ትዕዛዝ ሁለት፤ ከዚህ በታች ከ 4 እስከ 6 ላሉት ለእያንዳንዱ ጥያቄ በፊደል ተራ “ሀ” ስር ይዘርዝሩ እና በፊደል ተራ “ለ” ስር በተጠየቁት መሰረት ማብራሪያ ይስጡ።

4. በትምህርት ቤታችሁ የኬሚስትሪ ትምህርት ከሚቀርብባቸዉ የትምህርት መርጃ (መማሪያ) መሳሪያዎች (የተማሪዉ መፅሀፍ፣ የፕላዝማ ትምህርት፣ መምህሩ የሚያዘጋጀዉ መርጃ መሳሪያ፣ የተግባር ትምህርት /practical activities/) መካከል በመንፈቀ አመቱ ማጠቃለያ ፈተና ላገኙት ዉጤት :-

ሀ/ የበለጠ ያገዘዎትን የኬሚስትሪ የትምህርት መርጃ (መማሪያ) መሳሪያዎች በቅደም ተከተላቸዉ ቢያስቀምጡ።

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ለ/ ከላይ በ“4 ሀ” ስር ከዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች ባህሪያት ለዲያግራም (diagram)፣ ለአቶም ወካይ (symbol)፣ ለሞደል (model)፣ ለሞለኪዩል መዋቅርና ቀመር (molecular structure and fomula) ፣ ለስሌታዊ አገላለጽ (mathematical representation) እና ለተግባር (laboratory)፣ የሰጡትን አንፃራዊ ትኩረት ቢያብራሩ።

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ሐ/ ከላይ በ“4 ሀ” ስር ከዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች ባህሪያት ለቃል እና ለፅሁፍ ትንታኔ የሰጡትን አንፃራዊ ትኩረት ቢያብራሩ።

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መ/ ጉልህ አስተዋፅኦ አድርገዉልኛል ብለዉ በ“4 ሀ” ስር ለዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች ያልገለጹት በጣም ጠቃሚ ነዉ ብለዉ ያሰቡት የመገለጫ ባህሪያት ካለ ቢገልጹት።

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5. በትምህርት ቤታችሁ የኬሚስትሪ ትምህርት ከሚሰጥባቸዉ የትምህርት መርጃ (መማሪያ) መሳሪያዎች (የተማሪዉ መፅሀፍ፣ የፕላዝማ ትምህርት፣ መምህሩ የሚያዘጋጀዉ የትምህርት መርጃ መሳሪያ፣ የተግባር ትምህርት (practical activities)) መካከል ፡-

ሀ/ በአንፃራዊነት በማወዳደር በመንፈቀ አመቱ ማጠቃለያ ፈተና ላገኙት ዉጤት አነስተኛ አስተዋጥኦ ያለዉን የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያ(ዎች) ቢዘረዝሩ።

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ለ/ ከላይ በ“5 ሀ” ስር ከዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች ባህሪያት ለዲያግራም (diagram) ፣ ለአቶም ወካይ (symbol)፣ ለሞደል (model)፣ በሞለኪዩል መወቅርና ቀመር (molecular structure and fomula) እና ለስሌታዊ አገላለጽ (mathematical representation)፣ ለተግባር ትምህርት (practical activities) የሰጠዉን አንፃራዊ ትኩረት ቢያብራሩ።

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ሐ/ ከላይ በ“5 ሀ” ስር ከዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች ባህሪያት ለትንታኔ የሰጡትን አንፃራዊ ትኩረት ቢያብራሩ።

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መ/ ከላይ በ“5 ሀ” ስር ለዘረዘሯቸዉ የኬሚስትሪ ትምህርት መርጃ (መማሪያ) መሳሪያዎች መርጃ ሌላ የበለጠ መገላጫ ባህሪያት ካላቸዉ ቢያብራሩ።

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6. የኬሚስትሪ የትምህርት (መማሪያ) መርጃ መሳሪያዎች በምን መልኩ ቢዘጋጁ የበለጠ ሊያስተምር ይችላል ይላሉ፡-

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Appendix C: Chemistry test from fundamental concepts in grade 11 chemistry syllabus

Test for Grade 11 students

Grade and Section: ________

Roll no:__________________

Instructions: Carefully read each question. Choose and circle the best answer for each one. Time allowed: 40 minutes

1. The law of mass conservation; law of definite composition and law of multiple proportions apply to the ___class of matter.
   - A. Element
   - B. compound
   - C. Mixture
   - D. Solutions
2. Which of these electron transitions correspond to emission?
   - A. n = 2 to n = 4
   - C. n =5 to n =2
   - B. n = 3 to n = 4
   - D. n =4 to n =4
3. Which electron configuration is impossible?
   - A. $1s^2 2s^2 2p^6 3s^2$
   - C. $1s^2 2s^2 2p^6 2d^2$
   - B. $1s^2 2s^2 2p^6 3s^2 3p^6$
   - D. $1s^2 2s^2 2p^5 3s^1$
4. The molecule of the type MX_4 consists of four bonded pairs and no lone pairs. What structure is it expected to assume?
   - A. Square planar
   - C. Trigonal pyramidal
   - B. Trigonal planar
   - D. Tetrahedral
5. The boiling point of Group VIA Hydrides is as follows: $H_2O=100^0C$; $H_2S= - 61^0C$; $H_2Se= -14^0C$; $H_2Te= -2^0C$, the boiling point of H_2O, compared to other members of the series can be explained by
   - A. London dispersion forces
   - C. Hydrogen bonding
   - B. Dipole-induced dipole forces
   - D. Non polar covalent bonding

6. Resonance structures describe molecules that have

A. hybrid orbitals C. multiple electron-dot formulas
B. resonating electrons D. Equi-atomic number

7. Which one of the following forms the structure of the nucleus of the atom?

A. Electron and proton C. Neutron, electron and proton
B. Neutron and proton D. Neutron and electron

8. Which of the following statements is (are) correct regarding molecular geometries?

I. CH_4 is trigonal pyramidal in shape.
II. BF_3 is trigonal planar in shape.
III. XeF_6 is tetrahedral in shape.

A. I only
B. II only
C. III only
D. I and III only

9. Of the following which of the following is not true about size of atom or ion.

A. $F < F^-$ C. $Li < K$
B. $Sr < Sr^{2+}$ D. $H^+ < H$

10. Which one of the following has a polar bond and polar molecular property?

A. CO_2 C. CH_3F
B. O_3 D. BF_3

11. An atom in each of the following molecules does not obey the octet rule except____.

A. SF_4 C. XeF_6
B. BH_3 D. ClO_2

12. In which pairs are the two species both isoelectronic and isotopic?

A. ${}_{40}{}^{20}Ca^{2+}$ and ${}_{40}{}^{18}Ar$ C. ${}_{24}{}^{12}Mg^{2+}$ and ${}_{25}{}^{12}Mg$
B. ${}_{39}{}^{19}K+$ and ${}_{40}{}^{19}K+$ D. ${}_{56}{}^{26}Fe^{2+}$ and ${}_{57}{}^{26}Fe^{3+}$

13. Which of the following n, l, and ml values corresponds to 3p and 4f respectively?

   A. n=3, l=1, ml= -1, 0,1 and n=4, l=3, ml= -3, -2,-1,0, 1, 2, 3
   B. n=3, l=0, ml= -1, 0,1 and n=4, l=2, ml= -2,-1,0, 1,2
   C. n=3, l=1, ml= 0 and n=4, l=2, ml=,-1,0, 1
   D. n=3, l=1, ml=1 and n=4, l=2, ml= -2,-1,0, 1,2

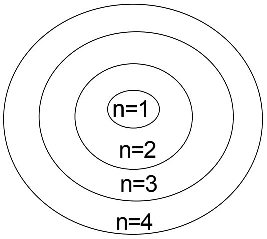
14. Formation of metallic bonding results in____.

   A. Greater electron density between the nuclei
   B. Delocalized valence electrons between the two atomic nuclei
   C. Electrostatic force exists between the two atoms
   D. Greater electron-nucleus attraction, electron-electron and nucleus-nucleus attraction

15. Which one of the following doesn't characterize the properties of electromagnetic radiation (EMR)?

   A. Energy of photon
   B. Frequency
   C. Wave length
   D. Speed

16. The following diagram illustrates Bohr's atomic model



   A. Energy of electron is quantized
   B. Electron has a circular orbit
   C. 'Electron occupies allowable orbit with a static energy level
   D. All of the above

17. All of the following are true except_____ for any vertical column of elements in the A groups of the periodic table, as you go from top to bottom:

   A. the number of electron shells decreases
   B. the number of valence shell electrons remains the same
   C. the ionization energy decreases
   D. The electronegativity decreases

18. Which of the following variables used for electromagnetic wave (EMW) to measure the strength of its electric and magnetic fields?

A. Electromagnetic spectrum
B. Threshold frequency
C. Work function
D. Amplitude

19. The fact that the two electrons in an orbital must have opposite spins presumed from;

A. Hund's rule of maximum multiplicity
B. Aufbau principle
C. Pauli's exclusion principle
D. Heisenberg's uncertainty principle

20. Which one of the following quantum number combinations is not allowed?

A. n=2, l=0, ml=0
B. n=4, l=3, ml=-1
C. n=3, l=1, ml=0
D. n=5,l=2,ml=3

21. Which of the following have paramagnetic properties in their ground states?

A. Ga
B. Si
C. Be
D. All of the above

Appendix D: Chemistry test from fundamental concepts in grade 12 chemistry syllabus

Test for Grade 12 students
Grade and Section: ________
Roll no:___________________

Instructions: Carefully read each question. Choose and circle the best answer for each one. Time allowed: 40 minutes

1. Which of the following is an example of Bronsted-Lowry acid-base models?
   A. $HCl + H_2O \rightarrow H3O^{1+} + Cl^{1-}$
   B. $HCO_3^{1-} + HSO_4^{1-} \rightarrow SO_4^{2-} + H_2CO_3$
   C. HCl is strong acid, while NaOH is strong base
   D. $:NH_3 + BF_3 \rightarrow NH_3:BF_3$

2. A molecule or an ion is classified as a Lewis base if it

   A. donates a proton to water.
   B. forms a bond by accepting a pair of electrons.
   C. forms a bond by donating a pair of electrons.
   D. accepts a proton from water.

3. A stronger base
   A. is also a stronger acid
   B. is also a stronger electrolyte
   C. tastes sour
   D. yields fewer OH^{1-} ions in solution

4. A substance is added to a solution containing two drops of phenolphthalein. The solution then turns pink. Which substance would produce this color change?

   A. HCl
   B. H_2CO_3
   C. KOH
   D. CH_3CH_2OH

5. Litmus is red when the H1+concentration in the solution is

   A. $1x10^{-11}$ M
   B. $1x10^{-9}$ M
   C. $1x10^{-7}$ M
   D. $1x10^{-5}$ M

6. Which is true about is acidic solution?

A. $[H1^{+}]$ equals zero.
B. $[OH^{1-}]$ equals $[H^{1+}]$.
C. $[H^{1+}]$ is less than $[OH^{1-}]$.
D. $[H^{1+}]$ is greater than $[OH^{1-}]$

7. According to the Bronsted-Lowry theory, a base can
A. donate a proton
B. yield H^{1+}ions
C. donate an electron pair
D. accept a proton

8. What volume of 0.200 M NaOH(aq) is needed to neutralize 40.0 mL of a 0.100 M HCl(aq)?
A. 100.0 mL
B. 80.0 mL
C. 40.0 mL
D. 20.0 mL

9. As an acidic solution is titrated with drops of base, the pH value of the solution will
A. increase
B. decrease
C. remain the same
D. approach zero

10. Which pH value demonstrates a solution with the greatest concentration of OH1− ions?
A. 1
B. 7
C. 10
D. 13

11. How many times stronger is an acid with a pH of 2 than an acid with a pH of 5?
A. A pH of 2 is three times as strong.
B. A pH of 2 is one thousand times as strong.
C. A pH of 2 is three times as weak.
D. A pH of 2 is one thousand times as weak.

12. Which pairing is not a set of Bronsted-Lowry's acid-base conjugate pairs?
A. OH^{1-} and H_2O
B. $HC_2H_3O_2$ and $C_2H_3O_2^{1-}$
C. HCl and Cl^{1-}
D. H_3PO_4 and PO_4^{3-}

13. Which of the following when added to water forms a buffered solution?

A. HF and NaF
B. HI and KI
C. HCl and NaCl
D. HNO_3 and $NaNO_3$

14. Which of the following is true about strong and weak acids?

A. If acid A ionized to the greater extent than acid B, then A is stronger
B. If acid C has a smaller Ka value than D, then acid C is stronger
C. If acid X is more concentrated than acid Y, then acid X is stronger
D. If acid K completely dissociates while acid N forms equilibrium in water, then acid K is stronger

15. Which one of the following factors affects buffer capacity?

A. Conjugate acid-base pair
B. pH of the buffer solution
C. Concentration of buffer components
D. Buffer range

16. Two systems at different temperatures come in contact. The heat will flow from the system at

A. 30 ^{0}C to a system at 317 K
B. 40 ^{0}C to a system at 323 K
C. 50 ^{0}C to a system at 303 K
D. 60 ^{0}C to a system at 358 K

17. How many joules of heat are released by a 150-gram sample of water that that cools from 25 ^{0}C to 5 ^{0}C? (c for H_2O is 4.18 J/gK)

A. 78,375 joules
B. 83.6 joules
C. 720 joules
D. 12,540 joules

18. Which one of the following is not a spontaneous thermodynamic process?

A. Rusting of iron
B. Dissolution of table salt in water
C. The flow heat from region of high temperature to a region of low temperature
D. Cleaning of a room

19. Which of the following is not true about aqueous solution of salt?

A. A salt solution derived from weak acid and weak base is neutral, if ka is equal to kb.
B. A salt solution derived from strong acid and weak base is basic
C. A salt solution derived from weak acid and strong base is basic
D. A salt solution derived from weak acid and weak is basic, if ka is less than kb

20. Which of the following is not true about titration of strong acid with strong base?

A. The pH is low at the beginning of the titration
B. At the equivalence point the pH is 7
C. Indicator whose color changes in the pH range from about 4 to 10 can be used
D. The initial pH is higher because the strong acid is completely ionized.

21. One of the following salts will yield a basic solution on dissolution in water?

A. Salt of weak acid and weak
B. A salt o f weak acid and strong base
C. A salt of weak acid and strong base
D. A salt of strong acid and weak base

22. A 0.1M solution of weak acid Hz is 0.059 percent ionized. What is the dissociation constant for the acid?

A. 4.2 x10-8
B. 4.2x10-6
C. 3.48x10-8
D. 34.2 x10-6

Appendix E: Amharic Version of Index of Learning Styles (ILS) Questionnaire

የተማሪዎች መጠይቅ (Index of Learning Styles Questionaire)

የክፍል ደረጃ፤ ሴክሽን እና መለያ ቁጥርዎትን ይፃፉ።

የክፍል ደረጃ እና ሴክሽን፡__________________________

መለያ ቁጥር፡__________________________

ይህ ጥናት የሚካሄደዉ ለዶክትሬት ዲግሪ መመረቂያነት የሚዉል የምርምር ስራ ነዉ። የጥናቱ አላማም፤ በመጀሪያ ተማሪዎች በሚመረጡት የመማሪያ መንገድና በኬሚስትሪ ትምህርት በሚያስመዘግቡት ዉጤት መካከል ያለዉን ዝምድና መለየት ሲሆን በሁለተኛ ደረጃ ደግሞ ተማሪዎች የሚያስመዘግቡትን የኬሚስትሪ ዉጤት ከሚጠቀመባቸዉ የመርጃ/መማሪያ መሳሪያ(ዎች) ጋር ያላቸዉን ግንኙነት እንዴት እንደሚገልጹት ለመረዳት ነዉ። የዚህ ጥናት ዉጤትም ተማሪዎች በኬሚስትሪ ትምህርት የተሻለ ተጠቃሚ የሚሆኑበትን መንገድ ሊጠቁም ይችላል።

በመሆኑም የዚህ መጠይቅ አላማዉ ተማሪዉ በተሻለ ሁኔታ የሚማርበት መንገድ (learning style) የትኛዉ እንደሆነ ለማወቅ ነዉ። ይህንንም ለማወቅ የሚያስችሉ 44 ጥያቄዎችን ይዟል። መጠይቁንም ለመሙላት 40 ደቂቃ ሊዎስድብዎት ይችላል። በዚህ ጥናት ተሳታፊ በመሆንዎና ጥያቄዎቹን ሙሉ በሙሉ ሰርተዉ በመመለስዎ ምስጋናዬ ከወዲሁ እጅግ ላቅ ያለ ነዉ።

ትዕዛዝ፤ ለእያንዳንዱ ጥያቄ አንድ መልስ ብቻ (ማለትም፡- ምርጫ “ሀ”ን ወይም “ለ”ን) በመምረጥ እና በመከበብ መልስዎትን ያመልክቱ።

1 አንድ ነገር የበለጠ የሚገባኝ፡-
ሀ/በተግባር ስሞክረዉ ነዉ።
ለ/ነገሩን ጊዜ ወስጄ ሳብሰለስለዉ ነዉ።

2 የተሻለ ሊገልፀኝ የሚችለዉ፡-
ሀ/ተጨባጭ(realistic) በሆነ ነገር ላይ ማተኮር ነዉ።
ለ/አዲስ ሀሳብ አፍላቂነቴ(innovative) ነዉ።

3 ትናንተ ያደረግሁትን ሳስብ የማስታዉሰዉ፡-
ሀ/በምስል (picture) ተደግፈዉ የቀረቡትን ነዉ።
ለ/በቃላት/በንግግር (words) ተደግፈዉ የቀረቡትን ነዉ።

4 ለመረዳት የሚቀለኝ፡-
ሀ/የትምህርቱን ዝርዝር እንጅ አጠቃላይ ጭብጡን አይደለም።
ለ/የትምህርቱን አጠቃላይ ጭብጥ እንጅ ዝርዝሩን አይደለም።

5 አዲስ ነገርን በምማርበት ጊዜ፡-
ሀ/ስለ ነገሩ ማዉራት ለመማር ይረዳኛል።
ለ/ስለ ነገሩ ማብሰልሰል ለመማር ይረዳኛል።

6 መምህር ብሆን ኖሮ ማስተማር የምመርጠዉ ትምህርት፡-
ሀ/ተጨባጭና (facts) ነባራዊ በሆነ ነገር ላይ የሚያተኩረዉን ነዉ።
ለ/ፅንሰሀሳብና ንድፈ-ሐሳብ (ideas & theory) ላይ የሚያተኩረዉን ነገር ነዉ።

7 አዳዲስ መረጃዎችን ማግኘት የምመርጠዉ፡-
ሀ/በምስል (picture)፣ በዲያግራም፣ በግራፍና በካርታ መልክ ነዉ።
ለ/በፅሁፍ ወይም በንግግር የቀረበ ሲሆን ነዉ።

8 አንድ ጊዜ፡-
ሀ/እያንዳንዱ ዝርዝር ሐሳብ ከገባኝ አጠቃላይ ጭብጡም ይገባኛል።
ለ/ አጠቃላይ ጭብጡ ከገባኝ ጭብጡን ከዝርዝር ሀሳቡ እንዴት እንደተዋቀረ መረዳት እችላለሁ።

9 አንድን ከባድ ነገር በቡድን የምሰራ ከሆነ እኔ የምመርጠዉ፡-
ሀ/ድንገት ጣልቃ በመግባት ለቡድኑ ሃሳብ ማቅረብ ነዉ።
ለ/ከሁዋላ ቁጭ ብሎ ማዳመጥ ነዉ።
10 ለመማር ቀላል ሆኖ ያገኘሁት፡-
ሀ/ተጨባጭእዉነታን (fact) ነዉ።
ለ/ፅንሰሀሳብን (concept) ነዉ።

11 ብዙ ምስልና ቻርት ባለዉ መጽሐፍ ዉስጥ፡-
ሀ/ ምስልና ቻርቱን በጥንቃቄ ማየት እመርጣለሁ።
ለ/ በተፃፈዉ ነገር ላይ ትኩረት ማድረግን እመርጣለሁ።

12 የሂሳብ ጥያቄዎችን በምሰራበት ጊዜ፡-
ሀ/ አብዛኛዉን ጊዜ ደረጃ በደረጃ (ያሰራሩን ቅደምተከተል ተከትዬ) (steps) ለጥያቄዉ መልስ እሰራለሁ።
ለ/ የጥያቄዉን መልስ ማግኘት ብችልም ያሰራሩን ቅደምተከተል (የተከተልኩተን መንገድ) በግልፅ ለማሳየት እቸገራለሁ።

13 በምማርበት ክፍል ዉስጥ ያሉ ተማሪዎችን ሁልጊዜም፡-
ሀ/ ብዙዎቹን ተማሪዎች አዉቃቸዋለሁ።
ለ/ ብዙዎቹን ተማሪዎች አላዉቃቸዉም።

14 ኢ-ልቦለድ ነገሮችን በማነብበት ጊዜ የምመርጠዉ/የሚቀናኝ፡-
ሀ/ ስለአዳዲስ እዉነታዎች (fact) የሚያስተምረኝን ወይም አንድን ነገር እንዴት መስራት እንደሚቻል መንገድ/ስልት የሚያሳየኝን ነዉ።
ለ/ አዳዲስ ሐሳቦችን በማቅረብ ይበልጥ እንዳስብ የሚያደርገኝን ነዉ።

15 የምወዳቸዉ መምህራን፡-
ሀ/ በጥቁር ሰሌዳ ላይ ብዙ ዲያግራሞችን የሚያቀርቡ መምህራንን ነዉ።
ለ/ ብዙዉን ጊዜያቸዉን ገለፃ በመስጠት የሚያሳልፉ መምህራንን ነዉ።

16 ታሪክ (story) ወይም ልቦለድ (novel) ድርሰትን በምተነትንበት ጊዜ፡-
ሀ/ መጀመሪያ ድርጊቶችን/ክስተቶችን (incidents) በማዉጣትና በማሰባሰብ ጭበጩን
አወጣለሁ።
ለ/ ልክ አንብቤ ስጨርስ ጭበጡን አወጣለሁ፤ ከዚያም ጭበጡን የሚያስረዱ ድርጊቶችን/ክስተቶችን (incidents) አወጣለሁ።

17 የቤት ስራ/ጥያቄ በምሰራበት ጊዜ፡-
ሀ/ ወዲያዉኑ/በቀጥታ መልሱን ለማግኘት ስራ እጀምራለሁ።
ለ/ መስራት ከመጀመሬ በፊት ጥያቄዉን በጥንቃቄ መረዳትን እመርጣለሁ።

18 እኔ የምመርጠዉ፡-
ሀ/ በተጨበጭ ደረጃ (certainty) ያለን ነገር ነዉ።
ለ/ በንድፈ ሀሳብ/ቲዮሪ (theory) ደረጃ ያለን ነገር ነዉ።
19 የበለጠ ማስታዎስ የምችለዉ፡-
ሀ/ የማየዉን ነገር ነዉ።
ለ/ የምሰማዉን ነገር ነዉ።

20 ለእኔ የበለጠ ጠቃሚነዉ የምለዉ መምህሩ፡-
ሀ/ ትምህርቱን ግልፅ በሆነ ቅደምተከተል የሚያቀርብ ከሆነ ነዉ።

ለ/ አጠቃላይ የትምህርቱን ጭብጥ/ምስል ጠቅለል አድርጎ የሚያቀርብና ከሌሎች ትምህርቶች ጋር ያለዉን ግንኙነት የሚያሳይ ከሆነ ነዉ።

21 ማጥናት የምመርጠዉ/የምፈልገዉ፡-
ሀ/ ቡድን በመሆን ነዉ።
ለ/ ብቻየን በመሆን ነዉ።

22 በይበልጥ እኔ የምታወቀዉ፡-
ሀ/ ስራየን በጥንቃቄ እና በዝርዝር በመስራት ነዉ።
ለ/ ስራዬን ለመስራት በማመጣዉ አዳዲስ የፈጠራ ስልት ነዉ።

23 ወደ አዲስ አካባቢ የሚመራኝን መረጃ ማግኘት የምመርጠዉ፡-
ሀ/ በካረታ ነዉ።
ለ/ በፅሁፍ ነዉ።

24 የበለጠ የምማረዉ፡-
ሀ/ በተመሳሳይ ቦታ (fairly regular place) ነዉ፤ ጠንከሬ ካጠናሁም ይገባኛል።
ለ/ ምቹ በሆነ ቦታ ማጥናት እንደጀመርኩ ሲሆን ከዚያም ቀስበቀስ መረዳት ያቅተኝና በመጨረሻም በድንገት ስራዉን አቁዋርጣለሁ።

25 መጀመሪያ የምመርጠዉ፡-
ሀ/ ነገሮችን መሞከር ነዉ።
ለ/ እንዴት መስራት እንዳለብኝ ማሰብ ነዉ።

26 ለመዝናናት በማነብበት ጊዜ የምመርጣቸዉ ደራሲዎች/ፀሃፊዎች፡-
ሀ/ መናገር የሚፈልጉትን በግልፅ የሚያስቀምጡትን ነዉ።
ለ/ ነገሮችን ፈጠራ በተሞላበትና ማራኪ በሆነ መልኩ የሚያስቀምጡትን ነዉ።

27 በክፍል ዉስጥ በዲያግራም ወይም ንድፍ (diagram or sketch)በማይበት ጊዜ በይበልጥ ማስታወስ የሚቀናኝ፡-
ሀ/ በምስል (picture) የቀረቡትን ነገሮች ነዉ።
ለ/ መምህሩ በክፍል ዉስጥ የተናገረዉን ነዉ።

28 አንድን ትልቅ መረጃ (body of information) በምመለከትበት ጊዜ በይበልጥ፡-
ሀ/ ትኩረት የማደርገዉ በዝርዝር ነገሮች ላይ እንጅ በአጠቃላይ ገለፃ/ሃሳብ ላይ አይደለም።
ለ/ ዝርዝር ሁኔታወችን ከመረዳቴ በፊት መጀመሪያ አጠቃላይ ጭብጡን/ሃሳቡን ለመረዳት እሞክራለሁ።

29 በቀላሉና በይበልጥ የማስታዉሰዉ፡-
ሀ/ እኔ ራሴ የፈፀምኩትን/የተገበርኩትን ነገር ነዉ።
ለ/ ብዙ ያብሰለሰልኩትን ነገር ነዉ።

30 አንድን ስራ በምሰራበት ጊዜ /መስራት ባለብኝ ጊዜ፡-
ሀ/በደንብ በምችለዉ አንድ መንገድ ስራዉን ማከናዎን እመርጣለሁ።
ለ/ የተለያዩ አዳዲስ መንገዶችን መጠቀምን እመርጣለሁ።

31 አንድ ሰዉ መረጃን እንዲያሳየኝ የምመርጠዉ፡-
ሀ/በቻርትና በግራፍ ነዉ።
ለ/በፅሁፍ ጠቅለል አድርጎ ቢያቀርብልኝ ነዉ።

32 አንድን ፅሁፍ በምፅፍበት ጊዜ፡-
ሀ/መጀመሪያ ማሰብና ፅሁፉን ጀምሬ እስከማጠናቀቅ ድረስ መቀጠል ነዉ።
ለ/ መጀመሪያ የተለያዩ የፅሁፉን ክፍሎች መፃፍና ከዚያም እያንዳንዱን ክፍል በተገቢዉ ቅደም ተከተል ማስቀመጥ ነዉ።

33 የቡድን ፕሮጀክት በምንሰራበት ጊዜ እኔ የምመርጠዉ መጀመሪያ፡-
ሀ/ የቡድን ሐሳብ አፍላቆት(brain storming) ማካሄድ እና ቡድኑ ሐሳብ እንዲያመነጭ ማድረግ ነዉ።
ለ/ በግል ሐሳብ አፍላቆት ማካሄድ እና ከዚያም በቡድን ተሰባስቦ ሃሳቡን መገምገምና ማነፃፀር ነዉ።
34 አንድን ሰዉ የማደንቀዉ፡-
ሀ/ነገሮችን የሚረዳና ምክንያታዊ ከሆነ ነዉ።
ለ/ፈጣሪ/አዲስ ሃሳብ አፍላቂ ተብሎ የሚጠራ ከሆነ ነዉ።

35 ብዙ ጊዜ በግብዣ ቦታ የማገኛቸዉን ሰዎች የማስታዉሰዉ፡-
ሀ/መልካቸዉ ምን እንደሚመስሉ ነዉ።
ለ/ስለየራሳቸዉ በተናገሩት ንግግር ነዉ።

36 አዲስ ትምህርት በምማርበት ጊዜ፡-
ሀ/በትምህርቱ ላይ ትኩረት በማድረግ እስከቻልኩ ድረስ ብዙ ለመማር እጥራለሁ።
ለ/ በአድሱ ትምህርትና በሌሎች ትምህርቶች ያለዉን ዝምድና በመለየት ለመማር እሞክራለሁ።
37 በይበልጥ ሌሎች እንዲረዱኝ የምፈልገዉ፡-
ሀ/በተግባቢነቴ ነዉ።
ለ/በቁጥብነቴ ነዉ።

38 እኔ የምመርጠዉ ትምህርት/ኮርስ፡-
ሀ/በይበልጥ የሚዳሰስ/ተጨበጭ፣ እዉነትና መረጃን ትኩረት የሚሰጠዉን ነዉ።
ለ/በይበልጥ ሃሳባዊ ነገሮች ላይ ትኩረት የሚሰጠዉን ነዉ።
39 እኔን በይበልጥ፡-
ሀ/ቴሌቪዥን ማየት ያዝናናኛል።
ለ/መፅሀፍ ማንበብ ያዝናናኛል።

40 አንዳንድ መምህራን ማስተማር የሚጀምሩት ስለሚያስተምሩት ነገር ቢጋር በማቅረብ ነዉ፤ በቢጋሩ መጀመር ደግሞ፡-

ሀ/ለኔ የተወሰነ መቀሜታ አለዉ።

ለ/ ለኔ በጣም መቀሜታ አለዉ።

41 በአንድ የክፍል ደረጃ ሙሉ በሙሉ የቤት ስራ በቡድን መስራት፡-

ሀ/ለኔ ደስ ይለኛል/ይመቸኛል።

ለ/ለኔ ደስ አይለኝም/አይመቸኝም።

42 ረጅም ሒሳብ (long calculation) በምሰራበት ጊዜ፡-

ሀ/ የተከተልኩዋቸዉን መንገዶች/ ቅደም-ተከተሎች እንደገና ደግሞ በመስራት ስራየን በጥንቃቄ አረጋግጣለሁ።

ለ/ የሰራሁዋቸዉን እንደገና መለስ ብሎ መከለስና ማረጋገጥ ለኔ አሰልቺና እንደገና ለመስራትም እራሴን ማስገደድ አለብኝ።

43 የነበርኩባቸዉን/የኖርኩባቸዉን ቦታዎች፡-

ሀ/በቀላሉና በትክክል/በተገቢ መልኩ በስዕል (picture) ማስቀመጥ እችላለሁ።

ለ/ በጣም ተቸግሬና ተጭናንቄ በስዕል ባስቀምጠዉም እንኩዋ ተገቢ/ ዝርዝር መረጃ መስጠት አይችልም።

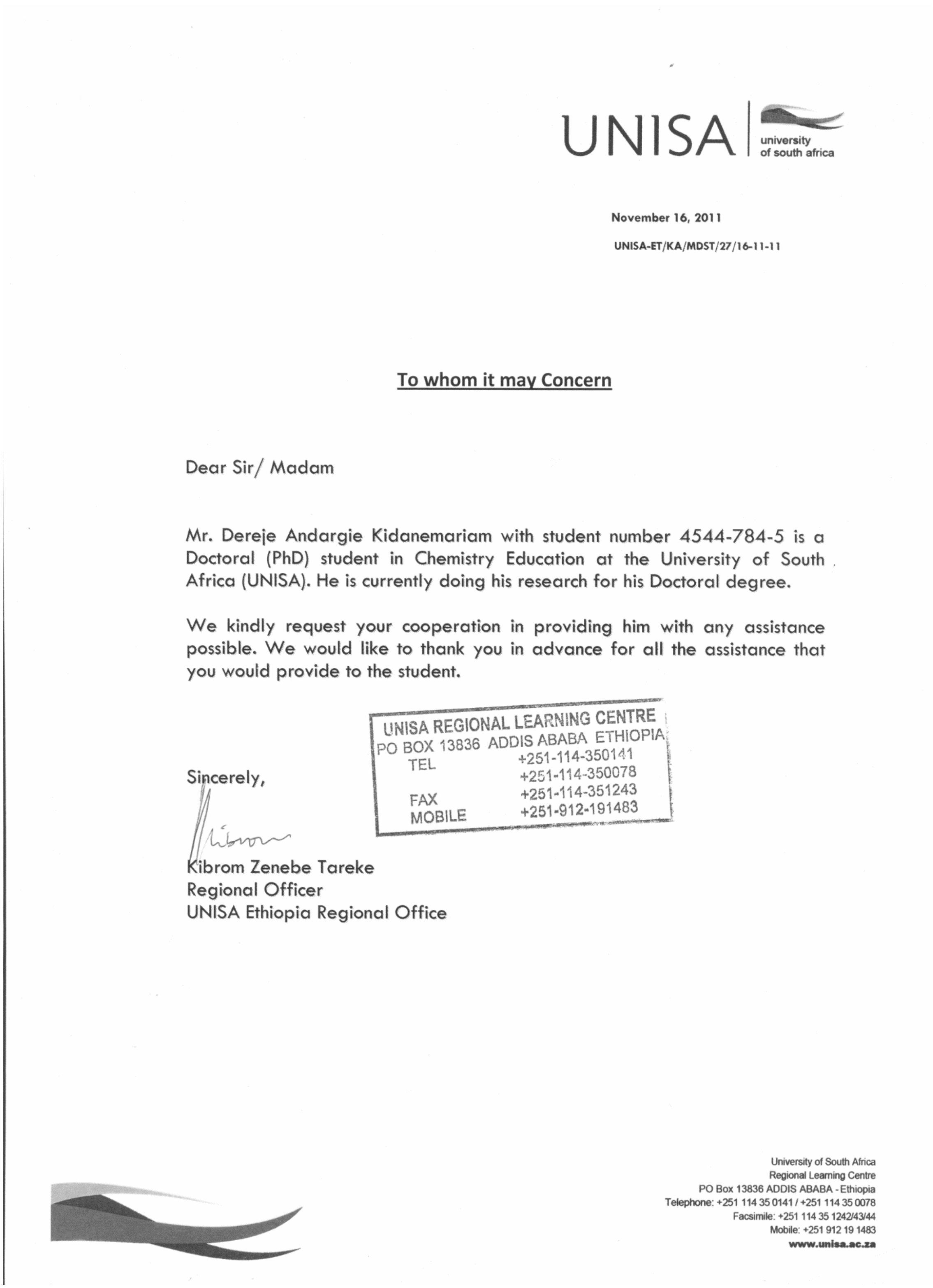
44 አንድን ችግር/ጥያቄ በቡድን በምንሰራበት ጊዜ የምመርጠዉ፡-

ሀ/ችግሩን/ጥያቄዉን የምሰራበትን መንገድ እያሰብኩ ነዉ።

ለ/ችግሩን/ጥያቄዉን በምንሰራበት ጊዜ መልሱ በሌላ ሰፋ ባለ ሁኔታ የሚያበረክተዉን በማሰብ ነዉ።

Index of Learning Styles Questionnaire with the permission of Richard M. Felder.
Hoechst Celanese Professor Emeritus of Chemical Engineering, N.C. State University
http://www.ncsu.edu/effective_teaching.
Index of Learning Styles © 1996, North Carolina State University

Appendix F: Support from UNISA Akaki center and Permissions from North Shoa District Education office to conduct the study



UNISA | university of south africa

November 16, 2011
UNISA-ET/KA/MDST/27/16-11-11

To whom it may Concern

Dear Sir/ Madam

Mr. Dereje Andargie Kidanemariam with student number 4544-784-5 is a Doctoral (PhD) student in Chemistry Education at the University of South Africa (UNISA). He is currently doing his research for his Doctoral degree.

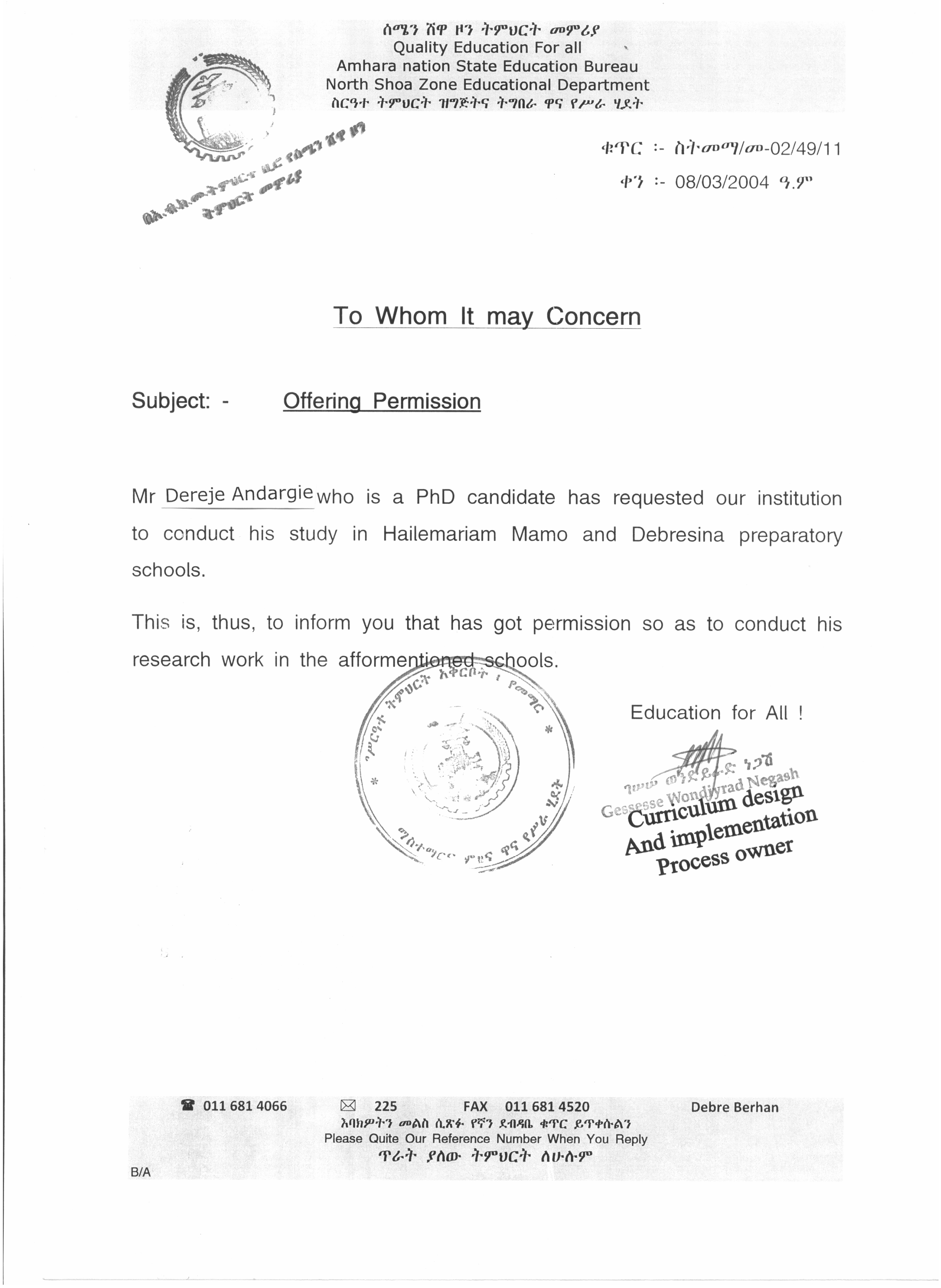
We kindly request your cooperation in providing him with any assistance possible. We would like to thank you in advance for all the assistance that you would provide to the student.

UNISA REGIONAL LEARNING CENTRE
PO BOX 13836 ADDIS ABABA ETHIOPIA
TEL +251-114-350141
+251-114-350078
FAX +251-114-351243
MOBILE +251-912-191483

Sincerely,

Kibrom Zenebe Tareke
Regional Officer
UNISA Ethiopia Regional Office

University of South Africa
Regional Learning Centre
PO Box 13836 ADDIS ABABA - Ethiopia
Telephone: +251 114 35 0141 / +251 114 35 0078
Facsimile: +251 114 35 1242/43/44
Mobile: +251 912 19 1483
www.unisa.ac.za



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North Shoa Zone Educational Department
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ቁጥር :- ስትመማ/መ-02/49/11
ቀን :- 08/03/2004 ዓ.ም

To Whom It may Concern

Subject: - Offering Permission

Mr Dereje Andargie who is a PhD candidate has requested our institution to conduct his study in Hailemariam Mamo and Debresina preparatory schools.

This is, thus, to inform you that has got permission so as to conduct his research work in the afformentioned schools.

Education for All !

ገሠሠ ወንድይራድ ነጋሽ
Gessesse Wondiyrad Negash
Curriculum design
And implementation
Process owner

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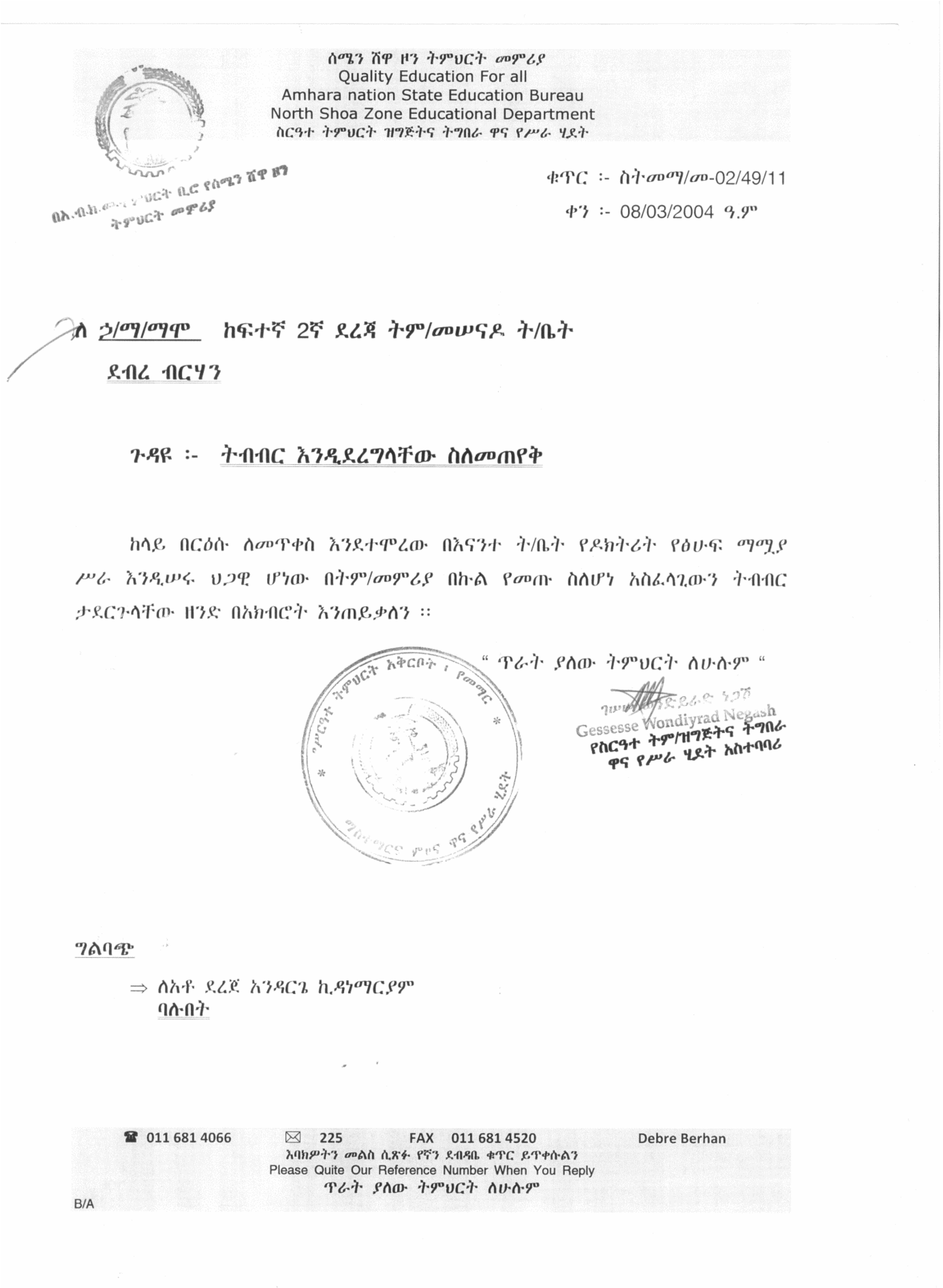

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በአ.ብ.ክ.መ [illegible] ህርት ቢሮ የሰሜን ሸዋ ዞን
ትምህርት መምሪያ

ቁጥር ፡- ስትመማ/መ-02/49/11
ቀን ፡- 08/03/2004 ዓ.ም

ለ ኃ/ማ/ማሞ ከፍተኛ 2ኛ ደረጃ ትም/መሠናዶ ት/ቤት
ደብረ ብርሃን

ጉዳዩ ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ

ከላይ በርዕሱ ለመጥቀስ እንደተሞረው በእናንተ ት/ቤት የዶክትሬት የፅሁፍ ማሟያ ሥራ እንዲሠሩ ህጋዊ ሆነው በትም/መምሪያ በኩል የመጡ ስለሆነ አስፈላጊውን ትብብር ታደርጉላቸው ዘንድ በአክብሮት እንጠይቃለን ፡፡

" ጥራት ያለው ትምህርት ለሁሉም "

ገሠ[illegible]ድይራድ ነጋሽ
Gessesse Wondiyrad Negash
የስርዓተ ትም/ዝግጅትና ትግበራ
ዋና የሥራ ሂደት አስተባባሪ

ግልባጭ

⇒ ለአቶ ደረጀ አንዳርጌ ኪዳነማርያም
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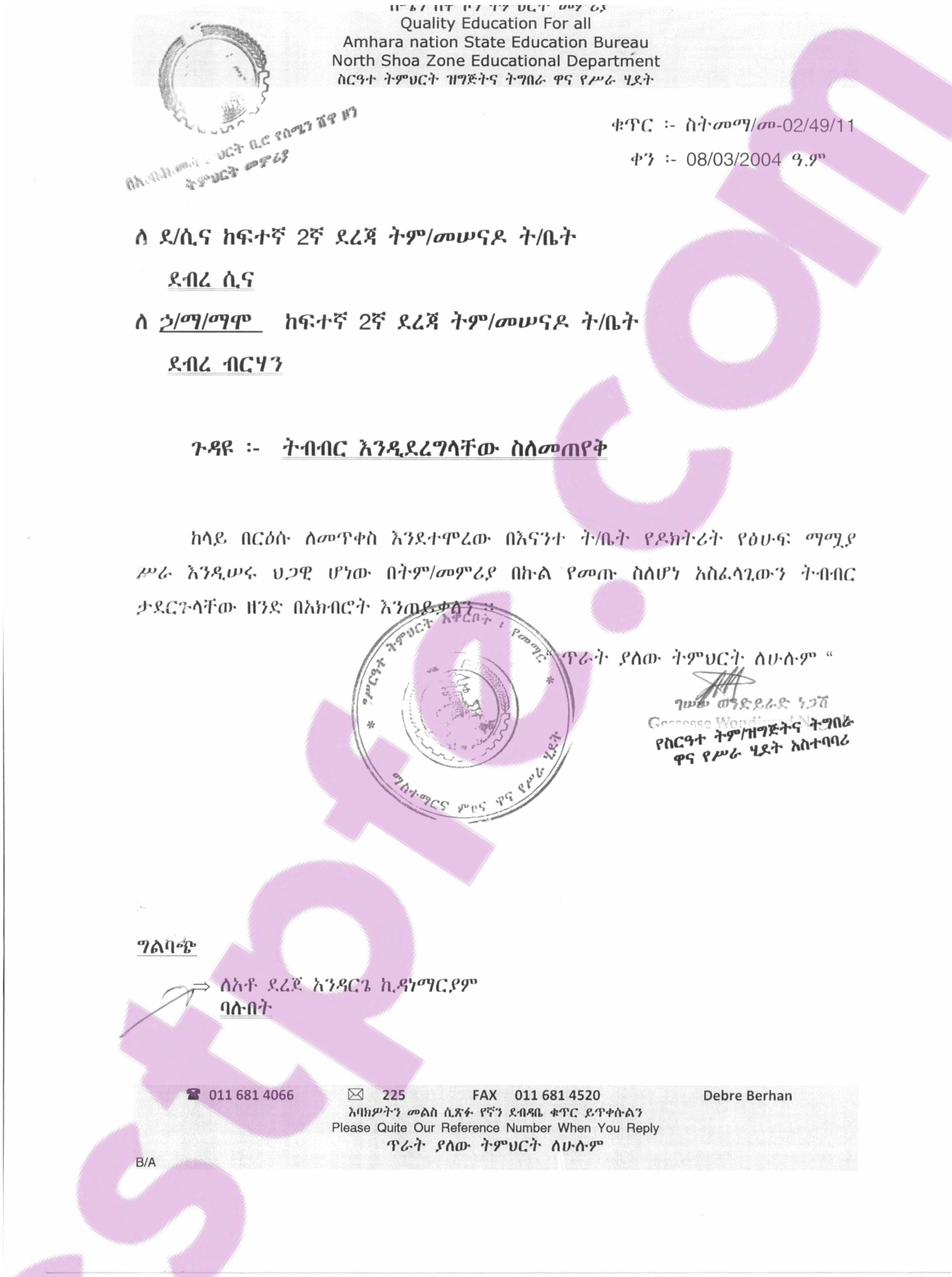

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ቁጥር ፡- ስትመማ/መ-02/49/11
ቀን ፡- 08/03/2004 ዓ.ም

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ደብረ ብርሃን

ጉዳዩ ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ

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" ጥራት ያለው ትምህርት ለሁሉም "

ገሠሠ ወንድይራድ ነጋሽ
የስርዓተ ትም/ዝግጅትና ትግበራ
ዋና የሥራ ሂደት አስተባባሪ

ግልባጭ

⇒ ለአቶ ደረጀ አንዳርጌ ኪዳነማርያም
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