

**Language Reasoning and Verbal Reasoning Difficulties of
Students in the four year BSc-Course at NWU
(Mafikeng Campus)**

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at the North–West University (Mafikeng Campus)

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DECLARATION

I declare that this project which is submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Chemistry (PhD) at North West University, Mafikeng Campus has not been previously submitted for a degree at this university or any other University.

The following research project was compiled, collated and written by me, Naledi Harriet Seheri-Jele. Sources of my information are acknowledged in the reference pages.

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ABSTRACT

Students who are learning science need to use specialized conceptual language in reading, reasoning and problem solving. This study explored the language used in chemistry including non-technical words (i.e., understanding of their meanings in both scientific and everyday contexts), and verbal reasoning skills (i.e., ability to draw conclusions from verbal statements/phrases). These words and skills seemed to pose a problem to some students studying chemistry as part of a BSc-Extended programme in the years 2013-2015.

The tool used was a quasi-experimental design, which was divided into three parts; pre-test, remedial instruction and post-test. The results were analysed by the SPSS method. The pre-test had 24 questions and the post-test had 7 questions testing the same skills. These questions were used to test aspects of language and verbal reasoning difficulties in learning chemistry and they include understanding of words such as qualitative and quantitative, description and explanation; ability to classify statements (as facts, principles, laws, theories etc.); ability to convert statements into equations; ability to represent information in diagrams; direct and inverse proportion reasoning skills; understanding of relationships between words; and applications of laws.

The pre-test results (2013 and 2014 random samples) indicated 45% failed the language skills and 65% failed the verbal reasoning skills tested.

The effect of the remedial instruction was confirmed by the post-test results, which were compared with the pre-test results for the experimental and control groups of students. The remedial instruction indicates that during student – student interactions, the students confused the meta-representational words (i.e., words like describe, explain) with logical connectives (i.e., because) in questions that required them to give reasons. This suggests that students struggle with language and reasoning abilities. Many of their difficulties were due to their

misunderstanding of the words used in the phrases or sentences given. The post-test results indicated that the performance of the experimental group increased by 35% while the control increased by 13%. Thus there was a significant statistical difference between the groups tested, in the language and verbal reasoning skills.

The study suggests that instructors may not sufficiently be addressing students' language difficulties, which affects students' ability in information processing and application skills. Thus they perform poorly in chemistry, not only due to lack of cognitive ability, but also due to inability to understand words and lack of verbal reasoning skills. Students thus need training in verbal reasoning skills, technical and non-technical vocabulary. All students are capable of thinking, but most of them need to be encouraged and assisted with the instructors playing a vital role. Students' exposure to chemical language should also be intensified, thus leading to better performance in chemistry.

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LIST OF ABBREVIATIONS

ACS	: American Chemical Society
CAPS	: Curriculum Assessment Policy Statements
DMV	: Dual Meaning Vocabulary
EFA	: Education for All
FSI	: Facilitator-Student interactions
IP	: Intervention Programme
IT	: Information Technology
KNEC	: Kenya National Examination Council
LOLT	: Language of Learning and Teaching
NWU	: North West University
NRF	: National Research Foundation
SAHE	: South African Higher Education
SAT	: CR-Scholastic Aptitude Test-Critical Thinking Reading
SPSS	: Statistical Package for Social Science
SSI	: Student – Student Interactions

CHAPTER 1

INTRODUCTION

1.1 Introduction

Extensive research has been conducted, in both education and psychology, concerning the nature of difficulties in learning science subjects such as chemistry. One of the reasons that chemistry is generally perceived to be a difficult subject by students is because of the language used and its abstract nature. There is heated debate in South Africa regarding the language of instruction in most tertiary institutions. The majority view is that it should be restricted to English, which is the second language to the majority of the students, including the cohorts in this study. For the cohorts in the study English was the second language although they came from different types of high schools and diverse backgrounds from various provinces within and also outside the borders of South Africa.

Chemistry involves not only interesting concepts and experimental activities, but also provides extensive knowledge for understanding the natural and manufactured worlds. It is however very complex. Students need to understand the symbols, terminologies and theories needed for learning chemical concepts, and they also need to transform the instructional language used by lecturers and the language used in the texts into meaningful representations. Students also need to understand the language used in order for them to make decisions and conclusions when considering verbal statements in chemistry. Herron (1996) argues that the language used in chemistry often makes learning difficult. One reason for this is that the meanings of some words in chemistry are different from their meanings in everyday language.

This study will be restricted to the chemistry curriculum. This incorporates concepts which are central to further learning in both chemistry and other sciences (Taber, 2002). Students need to understand fundamental concepts before going to more abstract concepts, and this is important because more difficult chemistry concepts and theories cannot be easily understood if these underpinning fundamental concepts are not sufficiently grasped by the student (Zolle, 1990; Nicoll, 2001). The abstract nature of chemistry along with other content learning difficulties means that chemistry classes require a high level skill set (Fensham, 1988; Zoller, 1990; Taber, 2002). High level skill set acquisition involves many factors, the most important seems to be good curriculum design, resources for better teaching of the subject and teachers/facilitators who have the required skills handling students with different levels of ability. Every student has a unique way of learning and this need to be considered in the teaching-learning process. The majority of first year students struggle to grasp and formulate meaning in chemistry. The reasons for this could include the fact that they are studying in a second language and facilitators often do not give sufficient thought to how students learn (Woldeamanuel, Atagan, and Engida, 2014).

Because there is a difference between the language needed for simple communication and for academic work, many teachers are not well trained to deal with learners with limited English proficiency (Adams and Sewry, 2010). In addition to this, the students in many programmes in South Africa come from diverse backgrounds. The majority of them are from rural schools, in which mother tongue is the first language and English is the second language. Although an academic literacy course is compulsory for all the first year students in our university, this may not ensure that students with limited English proficiencies can improve significantly in English as the course is only for one year.

The major teaching and learning challenges in higher education according to Knapper (2001, p.94) are "...instruction that is too didactic, a lack of personal contact between teachers and

among students, assessment methods that are inadequate to measure sophisticated learning goals and too little opportunity for students to integrate knowledge from different fields and apply what they learn to the solution of real world problems”. Teaching and learning in South African Higher Education (SAHE) seems to fit this description. In addition, large classes are an endemic feature of most university first year courses, which poses an additional challenge in the teaching of a diverse student population. Many students seem to not have the necessary knowledge and skills required for studying effectively, particularly in key areas such as mathematics and science (Paras, 2001; Howie and Peterson, 2001; Drummond 2003). Although our university has several methods to assist students in large classes, challenges still exist for the first year introductory chemistry course, where some students do not receive the necessary support, due to factors such as adapting to the university lifestyle and influence from their peers. Many students also skip classes in the academic literacy module and they seem to focus only on their major or core scientific subjects. This affects their language abilities and critical thinking skills (e.g. problem solving and information processing) which are of utmost importance throughout their academic years.

As universities come under pressure to increase the diversity of their student populations, assessing students’ potential for success in higher education has gained increasing importance. The South African school-leaving certificate is currently viewed as an inadequate measure of the students’ potential for success in higher education (Jaffer, Ng’ambi, and Czerniewicz, 2007). Problems with the ability of the school leaving certificate to predict success in higher education academic performance include the medium of instruction, inadequate school backgrounds and demographic variables of students (Yeld, 2001). Most universities have placement tests which are written by first year students, which are used in conjunction with school-leaving certificates to admit students with potential into higher education studies.

South Africa has eleven official languages and this diversity is also reflected in the student population of higher education institutions.

In this research two aspects were considered: language ability and verbal reasoning ability of students. Verbal reasoning involves the understanding of the verbal information given; and using them to carry out thinking and reasoning tasks. Language skills tested involve the understanding of the meaning of non-technical and non-scientific words used in normal everyday speech which are also used in scientific contexts.

1.2 Problem Statement

The problem studied is increasing the competence of students selected for the first year of the four year BSc course at the North West University, in the necessary language skills and verbal reasoning skills for learning chemistry effectively. The normal BSc program at the university is of three years duration and the four year program was started fairly recently. The four year program is meant for students who did reasonably well but did not qualify for admission to university, on their performance at the national senior certificate examination. In the first two years of the four year BSc program, students cover the first year syllabus of the three year BSc program and also are trained in addition, in many types of intellectual skills and strategies (which include language skills and verbal reasoning skills). Students who pass the second year of the four year BSc course are admitted to the second year of the normal three year BSc program. The main purpose of the study is identify the difficulties of students entering the four year BSc program in language skills and verbal reasoning skills, and to suggest methods for rectification of the difficulties.

1.3 Objectives of Study

The main objectives of the study were:

- (a) To identify the possible types of difficulties associated with language skills and verbal reasoning skills that would hinder effective learning of chemistry by content analysis of the chemistry syllabus.
- (b) To design a question paper (pre-test paper) to test students' competence in the skills identified above
- (c) To find out the extent of students' difficulties in language and verbal reasoning skills by the analysis of results in the pre-test ;
- (d) To develop and give a remedial instruction program to “experimental” groups of students to address the identified difficulties;
- (e) To check the effect of the remedial instruction by comparing the student performance in the pre-test and the post-test;
- (f) To make recommendations concerning the rectification of students' language and verbal reasoning difficulties

1.4 Significance of the study

Rectifying difficulties in language and verbal reasoning skills is important for students to learn effectively. The findings of the study can be used to design the chemistry course that enhances their language skills and their thinking and reasoning skills.

1.5 Limitations of the study

Since the pre-tests were conducted over a two year period, there was a long time lapse between the pre-test, the intervention programme (IP) and the post-test. For this reason, the performance of all students, not only the experimental group, may be expected to improve. Some students who wrote the pre-test were not in the IP and did not do the post-test, since this was a voluntary study. Some students also left the programme due to various reasons. Hence the numbers in the IP and post-test were smaller than in the pre-test. Audio recordings of the intervention programme were done. Unfortunately some of the recordings were not audible enough, and hence could not be analysed.

1.6 The Structure of the Thesis

Chapter 1 – Introduction – this chapter introduces the various aspects of language difficulties associated with learning and application of chemical knowledge, aims and objectives and the significance of the study

Chapter 2 – Literature Review – this chapter discusses the literature related to language and verbal reasoning difficulties in learning, both internationally and locally. The constructivist theory and the information processing theory are reviewed as the theoretical background for the present study. This chapter also tries to relate the appropriate research findings of other researchers to this study. It also debates specific issues faced in South Africa regarding the language of teaching and learning.

Chapter 3 – Methodology – this chapter describes how the different stages of the investigation were carried out and also the background of the cohorts in the study. It also considers the development of the question papers for the pre-test and post-test and the

analysis of each question. It also outlines how the intervention programme was conducted which includes the student-student interactions.

Chapter 4 – Pre-test Results and Discussions – this chapter discusses the results obtained from the two different groups of students studied. The chapter also describes the audio recordings of student-student interactions and discussions of the pre-test question papers, without the guidance of the instructor. It also summarizes the main findings and discusses their significance and implications.

Chapter 5 – Intervention and Discussions – this chapter focuses on the intervention program that involved facilitator – student interactions FSI. The instructor provided guidance for answering the questions in the pre-test. The main implications of the research findings were also discussed by the facilitator.

Chapter 6 – Post-test Results and Discussions – this chapter focuses on the results obtained from two different groups of students studied. It gives details of the main findings of the post-test and discusses them and compares the results with those in the pre-test to check if there was a significant change after the intervention.

Chapter 7 – Conclusion and Recommendations – this chapter summarises the results and discusses the implications of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many types of research studies have been done in the various types of cognitive skills associated with learning chemistry (Danili and Reid, 2004). Two learning theories will be discussed here, as these theories provided the theoretical basis for this research. The theories are the Constructivist learning theory and Information processing theory. This chapter will also discuss some of the research done on language and verbal reasoning skills. This is to get a clearer view about other researcher's findings so that they could be compared with findings of this research. It also includes the issues on language of teaching and learning in South Africa.

2.2 Constructivist Learning Theory

The underlying concept in the constructivist learning theory is the role in which students' experiences in conjunction with their learning atmosphere play an important role toward their success in learning (Bodner, 1986; Danili and Reid, 2004). Two key concepts within this theory which relate to the construction of an individual's new knowledge are accommodation and assimilation. Accommodation refers to reframing the world and new experiences into the mental structures already present in the individual. Assimilation involves the incorporation of new experiences into old experiences. This helps an individual to develop new outlooks, rethink and evaluate what is important.

In this theory, teachers are regarded as facilitators whose role is to aid the student to reach new understanding. Instead of having students relying on information provided by

facilitators, it postulates that students should be exposed to data and primary sources, and should be able to interact with other students. The constructivist teacher provides tools such as problem solving and inquiry based learning activities with which students formulate and test their ideas, draw conclusions and convey their knowledge in a collaborative learning environment (Danili and Reid, 2004). The constructivist theory was a shift from considering instruction primarily in terms of logical structure of the subject matter and the general intellectual level of the learner. It is effective in conceptualising teaching in terms of the necessary shift from where the learner's thinking currently is to where teachers envisaged it to be i.e., how each individual develops a unique system of personal constructs to understand the world (Leach and Scott, 2002). This theory has been selected to assist the researcher in the present study to postulate how students come up with meanings and clarifications when faced with new material, and how they relate and apply their knowledge when faced with individual work and also working collaboratively during group work. The theory was also applied during the intervention programme to observe the manner in which students share ideas and knowledge amongst themselves to reach logical conclusions. This theory encourages the collaborative mental efforts and sharing of ideas amongst students.

2.3 Information Processing Theory

This theory is based on the idea that people process information they receive rather than merely responding to stimuli. The theory encompasses many cognitive processes which include perception, reasoning, problem solving and conceptualization, (Kuhn, 1999; Halpern, 2003). People process information with amazing efficiency and often perform difficult tasks such as problem solving and critical thinking. It is the present researcher's belief that each person has a unique way of processing information, which can assist him/her to learn effectively. The information processing theory has three main components which are

associated with sensory-memory, working-memory and long-term memory ((Johnstone, 2006; Tobias and Duffy, 2009). These components are summarised in Figure 2.1

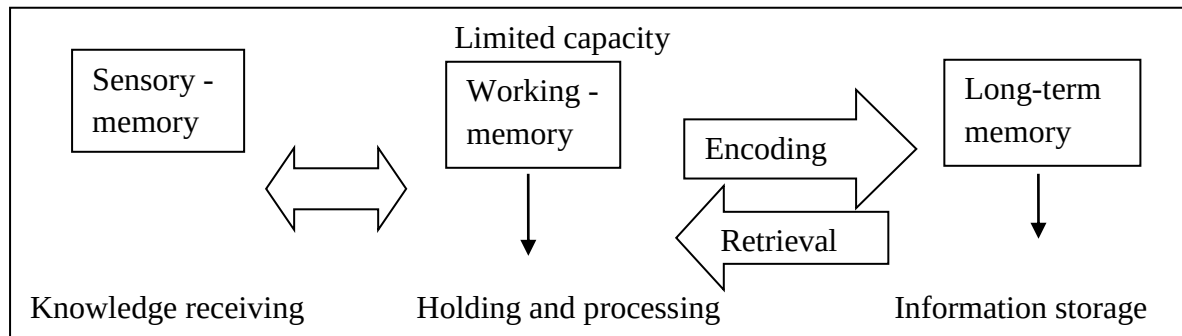


Figure 2. 1 Components of Information Processing Theory (Tobias and Duffy, 2009).

2.3.1 Sensory-memory

Sensory-memory screens incoming stimuli and processes only those stimuli that are relevant at any particular time. Researchers agree that information processing in sensory-memory usually occurs very quickly and that people do not consciously control it (Danili and Reid, 2004). Instead, attention-allocation and sensory processing are fast and unconscious. Information that is relevant to a task and information that is familiar and therefore subject to automatic processing in sensory-memory and forwarded to the working-memory.

2.3.2 Working-memory

Working-memory refers to a multi-component temporary memory system in which information is assigned meaning, linked to other information, and essential mental operations such as inferences are done (Baddeley, 2003). Most people have severe limitations in how much mental activity they can engage at a particular time (Kane and Engle, 2002). Although learners differ with respect to available cognitive resources, all learners experience severe limitations regardless of their skill and ability level. Taber (2013a) indicated that the working memory is where people can process information when doing calculations, planning a piece of writing and developing a problem-solving strategy. The working memory is considered as

the “mental scrapbook” that allows a person to store and manipulate information while engaging in other tasks. The student’s ability to master content of daily instruction is mostly dependent on their ability to process information successfully in the working (Baddely, 2000) memory.

When students are faced with learning situations where there is too much to handle in the limited working space, this causes difficulty in selecting important information from less important information. The researcher used this theory to assess how students answered the pre-test and also to explain how they behaved during student-student interactions, when faced with information that causes difficulty to them. Sirhan (2007) indicated that the chemistry student needs to develop skills to organize the ideas so that the working space is not overloaded when faced with new and conceptually complex material. Although Sirhan mentioned that students need to develop skills to organize ideas, I believe that also how students are taught and guided through their learning can affect their ability in developing skills to organize the ideas in working memory. Sweller (2007) mentioned that the limitations on the working memory may be adaptive based on the environment. In the current situation that often prevails of overcrowded classes, it is difficult to identify students with limited learning abilities in terms of organization of knowledge and grasping new ideas. The issue, explored in this research, is whether the environment really affects the students’ ability to cope, particularly when placed in small group settings during student-student and facilitator-student interactions. Watson and Gable (2011) discussed the role of attention in the classroom, and found that students who have difficulty in paying attention to specific information struggle with encoding (i.e. initial acquisition) of information. They considered attention to be the cognitive process that supports the working memory, and allows students to make efficient use of working memory. Many factors can influence students’ attention, such as motivation, anxiety and fatigue. If students’ attention is disturbed; their opportunity

to learn is diminished. They had also mentioned that if students cannot control their attention, interfering information will not be filtered out and this will adversely affect their learning.

Taber (2013a) mentioned that the limited information processing capacity of the typical human brain is a major restriction on cognition. This might be considered as the “bottleneck” or “rate determining step” that limits activities such as problem-solving and new learning (Kouider and Dehaene, 2007). Taber (2013a) mentioned that human beings may have evolved cognition which is better adapted to a hunter-gatherer lifestyle than to learning in schools and university classes. I agree that every individual has his/her style of learning and processing information which can assist their effective learning and problem solving. In this regard the constructivist theory suggests that the teacher plays vital roles in guiding but not necessarily doing work for students.

2.3.3 Long-term memory

Compared to sensory and working memories, long-term memory is not constrained by limitations in capacity or duration of attention. Most researchers believe that long-term memory can hold millions of pieces of information for very long periods of time (Anderson, 2000). Two aspects of long-term memory that have been extensively researched are (i) types of information that are organised and (ii) how information is stored. The long term memory can be divided into two types, declarative memory (i.e. episodic and semantic) and non-declarative memory. The declarative memory is considered to be the conscious memory, which involves describing, remembering of facts, objects and names. The declarative memory had been divided into two; episodic memory which deals with personal experience of an individual and semantic memory deals with gathering facts and verbal information.

Whereas the non-declarative memory which is implicit refer to memories that can be recalled without requiring more mental effort, and it has also been divided into two types which are;

Procedural memory which is used for performing tasks and applying learnt skills and associative memory which involves the process of forming ties between stimuli and response, learning whereby the individual responds to things without being consciously attentive (Kandarakis and Poulos, 2008).

A comparison of the three components of information processing theory indicates that sensory and working memories are short term. They can be used to manage only limited amounts of incoming information during initial processing. Their main roles are to screen incoming information, assign meaning and relate individual units of information to other units. In contrast, long-term memory is a permanent repository for knowledge. Long-term memory serves as a highly organised permanent storage system. The main processing constraint concerning long-term memory is an individual's ability to quickly encode and retrieve information from it (Shah and Miyake, 1999; Baddely, 2001).

There are four major pillars in the information processing approach: thinking, analysis of stimuli, situation modification and obstacle evaluation (Miller, 2003). Thinking includes the perception of external stimuli, encoding the same and storing the data. Analysis of stimuli is the process by which the encoded stimuli are modified to suit the brain's cognition and interpretation processes to enable decision making. Four main sub-processes need to form a favourable alliance for the brain to arrive at a conclusion regarding the encoded stimuli: encoding; strategization; generalization and automization (Stanovich, 2003). The third pillar stated above, situation modification, is a process by which an individual uses previous experience to handle the problem. The last pillar, obstacle evaluation, suggests that besides the subject's individual developmental level, the nature of the obstacle should also be taken into consideration when evaluating the subject's intellectual, problem solving and cognitive development (Rogers, Miller, and Judge, 1999; Miller, 2003).

2.4 Information Processing in Teaching and Learning

There are four important implications of the information processing model for effective learning and instruction, which will be discussed incorporating other researchers' views regarding memory.

The first is that memory is extremely limited in both sensory and working-memories. Two important strategies that can be used to cope with the limited capacity of working-memory are selective focusing on important information and automated processing. Automation will enable the limited processing resources to be used in engaging labour intensive regulation (Buttler and Winne, 1995).

A second implication is that relevant prior knowledge will facilitate encoding and retrieval processes. Effective learners generally possess a large amount of organised knowledge within a particular domain such as reading, mathematics or science concepts. This knowledge will help to guide information processing in sensory and working memories by providing easy access retrieval structures in memory. It also serves as the basis for the development of expertise, and thus helps the student to use prior knowledge when learning new information. This will promote effective learning (Alexander, 2003; Ericson, 2003).

A third implication is that automated processing increases cognitive efficiency by reducing information processing demands. Automaticity is a very important aspect of effective learning because it allocates the limited resources concerning working memory to information that is most relevant to the learning task, and also enables the limited resources to be used for drawing inferences and connecting new information to existing information in memory (Stanovich, 2003).

The fourth implication is that learning strategies can be expected to improve information processing because learners are more efficient and process information at a deeper level (Pressley and Harris, 2006). Good learners use a variety of strategies and use them in a highly automatic fashion. There are three general strategies that all effective learners use in most situations. They are organization, inference and elaboration (Mayer and Maren, 2003). Organization refers to how information is sorted and arranged in long-term memory and this includes how information is stored, encoded and retrieved. Inferences involve making connections between separate concepts, while elaboration refers to increasing the meaningfulness of information by connecting new information to ideas already known.

2.4.1 Studies on the effects of memory in learning.

Baddeley (2003) states that working-memory space is of limited capacity. This limited space is a link between what has to be held in the conscious memory and the processing activities required to handle it, transform it, manipulate it and store it in long term memory. When students are faced with learning situations where there is too much information to handle in the limited working space, they have difficulty in selecting important information from less important information. Faced with new and complex material, the student needs to develop skills to organise ideas so that the working space is not overloaded. The ability to develop strategies to cope with information overload depends on the conceptual framework already established in the long-term memory. On the other hand, the constructivist view regards learning of new material to be more directed towards the students, with the guidance of the teacher. The teacher makes use of the students' pre-existing conceptions, and guides them on how to address the activity on their own. The learning here is more interactive between the teacher and students. Students are encouraged to link their pre-existing knowledge to real life scenarios.

Cognitive structures determine how information is perceived, organised, stored, retrieved and used. Danili and Reid (2004) indicated that the flow of information through the cognitive system can be regarded as consisting of information input, output and mental operations which process information between input and output. They suggest that the processes necessary for the understanding of chemistry are different from processes required to comprehend everyday events. Danili and Reid (2004) have studied the effects of working-memory space and field dependency on the learning of chemistry by Greek students. They found that learning of all new information will fail if the working-memory space is overloaded. This will occur if students are given too much information at once. They suggested that chunking and grouping pieces of information can be used to reduce the demands on the amount of information to be held in the working-memory. Chunking will be affected by students' prior knowledge, experience and skills in a particular subject. Although Danili and Reid (2004) used chunking as an effective tool in addressing students' problems in storing information, during individual work, the constructivist view is that if students can be grouped rather than working alone, they can share ideas on how to arrive at the solution to the problem given. The small group setting has advantages of being more interactive and more information can be contributed by different members within a group. The setting is more conducive to leading students to reflect and connect, which supports the idea of memory input and output.

2.5 Language and Learning in Chemistry

This section will discuss different researchers' findings regarding the use of language in chemistry and how it affects the students' learning and the teaching-learning process.

2.5.1 Language in Information Processing

White (1977) argued that learning involves the interaction of the information that the learners receive through their sensory systems and the information they already have in their long-term memory. This enables the learner to recognise and organise the incoming information and make sense out of it. Unfamiliar words and constructions can come in conflict with the organisation process. White also emphasized that the cognitive processes may be considered to involve the interaction of the components of working and long-term memories. The present study intends to find out if non-technical words used in everyday language can also cause confusion to the students when they process or interpret the questions and hence result in their giving wrong answers. Although White mentioned “unfamiliar words,” there is a possibility that even familiar words can cause confusion and result in students’ failure. This aspect will also be investigated in the present study.

Language can help or hinder interactions within long-term memory. It can also be a source of information overload (Johnstone, 1984) and may influence the thinking processes necessary to tackle any task. Cassels and Johnstone (1984) found that the memory span is not determined by the number of words but by the grammatical clauses that may load memory. They stressed that the important factor in the sentence is its meaning, with sentences that are “negative” requiring more working-memory capacity than identical sentences written positively. Hence in this study we want to find out if the non-technical phrases/ language are also a problem for students to derive meaning and to reach logical conclusion.

According to Nentwig, Demuth, Parchmann, Gräsel, and Ralle (2007), scientific literacy is perceived as an intersection of knowledge, activities and values. Bennett, Lubben and Horgath (2007); and King (2012) mentioned that the benefits of these approaches are that

students often find context-based chemistry more interesting and motivating than conventional approaches.

2.5.2 Language in Learning Chemistry

The study by Cassels and Johnstone (1980) showed that even non-technical words associated with science were often a cause of misunderstanding for students. The study indicated that words which were understandable in normal English usage sometimes changed their meaning when transferred into or out of a science situation. For example, the word “volatile” was used by students to mean “unstable” or “flammable” whereas its scientific meaning of “easily vapourised” was not clear to them. Although this study also involves non-technical words, we are not using similar questions to those used by Cassels and Johnstone, since the objectives of our study are different.

Maznah and Zurida (2006) studied the comprehension of some non-technical words by form four students in Malaysia, in different streams: art, engineering and science. They gave the following example of a question that tested the word “abundant” in a scientific context.

There was an abundant supply of gas to the reacting chemicals. This means that

- (a) There was a shortage of the gas,*
- (b) The supply of gas was just enough for the reaction,*
- (c) The gas was not suitable for the reaction, and*
- (d) There was plenty of gas for the reacting chemicals.*

They compared the results with those obtained by Johnstone and Selepeng (2001). They found that students from the art class scored much lower than those in engineering and science. They also indicated that 82% of the science students and 76% of engineering

students communicated in English at home, but only 28% of the arts students spoke English at home. Their findings indicate that students speaking English at home showed a higher comprehension level than those students who do not speak English at home.

Oyoo (2011) used an example from a physical science examination question paper, as cited from Kenya National Examination Council report. Students were asked to “distinguish between ductile and brittle material”. The students could only define the terms but could not distinguish between them. He also interviewed the students regarding their difficulty in responding to test questions, and some students’ responses were as follows:

- (a) Student 1: If you don’t understand the meaning of the words in the topic, when these words are used in the exam, you will fail the paper because you do not know the word meanings.
- (b) Student 2: Lack of knowledge of the meanings of the words leads to time wastage during examinations because one takes a lot of time fumbling with the word meanings and end up failing the exam just because of the meaning of a word.

Oyoo (2011) observed that the types and trends of the difficulties encountered are the same, irrespective of whether the students learn science using their first language or not. He pointed out that the instructional language used by science teachers is generally a challenge to most students even when non-technical words are used. In addition to this he recommended that students who learn science in a second language, need some level of proficiency in the language of instruction as a pre-requisite for learning. Although Oyoo mentioned this, the question still arises on what will be the best method to make sure that students are proficient, and whether university admission criteria are enough to ensure the success of students who wish to continue with chemistry at higher levels. Since chemistry itself is a cumulative subject, whereby students continue to meet new terminologies throughout their studies, non-

technical words in science can still pose a serious problem for students at higher levels of their study.

Oyoo (2011) also studied students' difficulties with non-technical words in learning science. He divided the non-technical words used by the teacher in a classroom into three categories: non-technical words in the science context; meta-representational terms and logical connectives. Non-technical words used in the science context have generally been considered as a part of science language, for example the word "diversity" in biology and "reaction" in chemistry. Meta-representational words refer to non-technical words that signify thinking and also words such as describe, explain, argue, observe, classify, analyse, conclude, deduce, interpret, define, investigate and infer. Logical connectives refer to words such as if, because, moreover, therefore, in order to, consequently and since. The value of these words depends on their meaning, which might enhance students' understanding of the demands of the questions. Some of the meta-representational words mentioned by Oyoo are included in the test question papers, to find out if students can differentiate between them.

Song and Carheden (2014) studied Dual Meaning Vocabulary (DMV) words in learning chemistry. These are words that have both scientific and everyday meanings. They used three themes to explore how college students provide meanings of the DMV before and after instruction. In the first theme students were requested to give the meaning of the DMV before instruction, and some students responded this way;

- (a) When asked to provide the meaning of the word "*base*", one student indicated that the word *base* means "the bottom like a podium or stand" in everyday language. But when asked for the meaning of the word in scientific context students indicated acid-base reactions without further clarification.

- (b) When asked about the words salt and organic, a student responded that “*salt*” was something you put in food. Students could not give reasons why “NaCl” is considered as a salt. Another student said the word “organic” was for vegetables and stuff that is grown without fertilizers, or healthy foods.

The second theme that Song and Carheden (2014) investigated was how traditional lecture-based instruction had an impact on students’ learning of scientific meanings of DMV. Students were asked what came to mind when hearing/reading the DMV after chemistry course presentation and concept examination, which was taken from the fundamental biochemistry course. The course was divided into three sections i.e., general chemistry, organic chemistry and biochemistry. The following was given:

- (a) When asked about the word “aromatic” one student indicated that it is something with a smell. To add (b) and (c) from the source

The third theme explored the challenges faced by students in learning the DMV in relation to their frequent use of the words, their study habits and lack of prior knowledge of other scientific vocabulary. Their findings indicated that;

- (a) Students cited that their struggle in understanding DMV is due to the lack of time spent on these words in class.
- (b) Students also indicated that outside the classroom these DMV words have different meanings. They also said that English vocabulary is easier to learn than scientific vocabulary.
- (c) When students were asked how they studied chemistry, they mentioned flashcards that they used to study for exams or quizzes.

Song and Carheden (2014) concluded that students demonstrated the tendency to select familiar everyday meanings over chemical meanings of DMV and they struggled to contextualize the scientific meanings of the DMV words.

Ver Beek and Louters (1991) studied the ability of American first year undergraduate students to solve “language” problems in chemistry. They noticed that students could solve problems of increasing difficulty until they had to work with one additional language item they did not understand. In single step problems the subjects in Ver Beek and Louters’ study could solve 91% of common language problems, and 82% of chemical language problem. In three step common language problems the success rate was 86%, but in three-step chemical language problems this dropped to 32%. They suggested that students’ exposure to chemical language should be intensified, that teachers should not assume that students are familiar with chemical terms and that terms should be introduced carefully. Gabel (1999) noted that students’ success rates with chemistry may not necessarily be related to the subject matter itself but to the way of teaching it. Danili and Reid (2004) indicated that difficulties in learning chemistry can be precipitated by a lack of chemistry language skills. This is in agreement with what constructivist view suggests; that the teacher must guide and actively involve the students, such that they can be more independent and construct their own meaning, unlike relying on teachers to provide them with information.

2.5.3 How teaching of chemistry affects students’ understanding

Another important factor which can affect students’ learning and language understanding is the way in which teachers present their lessons. The constructivists’ views are that sharing of ideas and open conversations amongst the teacher and students can enhance understanding of non-technical phrases presented to students. Mji and Makgato (2006) cited that the Education for All (EFA) assessment report of 2000 and 2005 indicated that in spite of approximately

85% of mathematics educators in South Africa being professionally qualified; only about 50 % have specialized in mathematics in their training. Similarly though 84 % of science educators are professionally qualified, only about 42 % are qualified in science. In some instances schools have even opted not to offer mathematics and physical sciences due to the lack of facilities and equipment to ensure effective teaching and learning. This situation has resulted in the teaching of physical science at the theoretical level, without any practical work being done to enhance understanding and application of knowledge. Some high schools in South Africa have opted for learners to take mathematics literacy instead of pure mathematics, which poses a serious threat to the number of students being attracted to science related courses at tertiary institutions. The South African government has stated clearly that one of its aims is to achieve equitable access to higher education for previously disadvantaged learners, with diverse educational backgrounds (Hardman and Ng'ambi, 2003).

A study conducted by Jaffer *et al.*, (2007) on higher education students and academic staff's access to and use of computers in five South African universities revealed that 39% of respondents spoke English as a home language while 61% spoke other languages. This indicates that the majority of the students in South African higher institutions use English as a second language. Gee (1990) and Cummins (1996) reported that language and academic success are closely related. They mentioned that academic language proficiency is far more difficult to acquire for students learning in their second or third language.

An important issue in South Africa is increased and equitable access to higher education, particularly for previously disadvantaged students. The four year BSc programmes were introduced to address this issue and to allow access to students with diverse backgrounds, who passed the matric examinations with a verdict of bachelors (i.e. are allowed to study for a bachelors degree) but who do not qualify to go into three years BSc programmes due to

their grades in subjects such as mathematics, physical science and English, for which they often obtained grades of 40-49%. However, this does not necessarily mean that every student can progress to higher levels in chemistry or other science programs, looking at several factors like educational background and socio-economic factors which can affect their learning (i.e. funding for tuition, learning materials and even food).

Oyoo (2012) gave an example of the background of some of the teachers which he observed in one of his studies. He reported on the manner in which physics teachers in Kenya used instructional language, and how their approaches could cause students' difficulties in learning and retention of scientific concepts and non-technical words. The qualifications (i.e. diploma or degree) and teaching experiences of the teachers who participated in the study varied. Teachers used different styles and approaches, and he observed the following:

- (a) The teachers were the sole controllers and did most of the talking during the lessons;
- (b) Teachers selected who to talk among students (even if their hands were not raised);
- (c) Students were not expected to verbalise any concerns;
- (d) Teachers refused to give answers to questions asked;
- (e) Teachers rushed through the lessons hence giving no time for students' questions.

Oyoo (2012) concluded that the use of language for effective communication in classrooms needs to be emphasized in initial science/physics teacher education and in in-service professional development programmes. This might assist teachers at the beginning of their career to take into cognisance the issue of language problems encountered by students. He also suggested that novice teachers could be guided and assisted by senior teachers, and teachers could share ideas on different teaching styles and approaches. This might result in better understanding on how to handle students and assist them to learn effectively.

Although I agree with Oyoo's recommendations, the problem still arises that teaching-learning is still largely based on traditional methods. I contend that students should be encouraged to be more independent, rather than relying on a teacher as the sole person who comes with ideas. The backgrounds of students in this study differs a lot, whereby the majority are from rural areas which do not have resources such as a library, internet and other sources where students can have access to information, thus they rely on the teacher and the textbooks provided, although some are from schools which are well-equipped. The situation is exacerbated by the fact that some of the teachers who teach science also had limited resources and limited proficiencies in the teaching of chemistry as mentioned above by Mji and Makgato (2006). The South African government has developed support structures to assist these teachers as mentioned in the "Department of Basic Education: Action Plan to 2019: Towards the realisation of Schooling 2030 pg 34" however, I believe that curriculum designers and educational policy makers must further investigate what students need and how can it be accomplished particularly in the language of instruction.

Chemistry by its nature is highly conceptual; while rote learning is often reflected by efficient recall in examination questions, real understanding demands the bringing together of conceptual understanding in a meaningful way (Sirhan, 2007). The current system in most universities for testing student is still based on the old model of pen and paper examinations, which I believe can hinder students' ability to reflect, recall and apply knowledge. It may be better if universities start to develop other modes of assessment which can enhance more meaningful ways of applying chemistry knowledge. Johnstone (1984, 1991) indicated that the nature of chemistry concepts can be represented in three levels, by the corners of a triangle, which are macroscopic, microscopic and representational as shown in Figure 2.2. It is often difficult for students to grasp these different levels of chemistry.

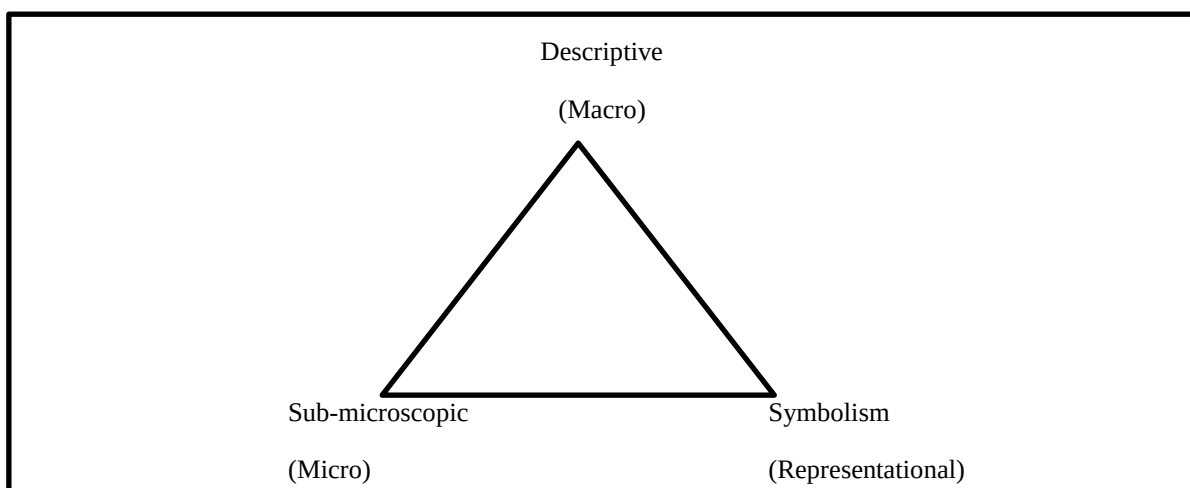


Figure 2. 2 Multilevel thought (chemistry triangle) (Johnstone 1991)

Johnstone (1982) has argued that rather than teaching being focused at one apex or even along one side of the triangle, it is better to do teaching inside the triangle where students are expected to cope with all three levels. Johnstone indicated that no one apex of the triangle is superior to the others, but each complements the others. Middlecamp and Kean (1988) mentioned that it is not uncommon for twenty concepts to be introduced in the course of a period of an hour. If this is true, based on the nature of the students' background in general first year entry courses, it will be advisable if facilitators can come up with methods to address students' limitations in coping with the abstract nature of chemistry, including language used. Some facilitators do try to come up with measures to address students' needs, but minimal time allocation also affects their facilitation process.

Gabel (1999) conducted studies on introductory chemistry courses to determine whether student's understanding would increase if the emphasis was on the particulate nature of matter at the sub-microscopic level. Gabel used two groups: the experimental group were given extra instruction that required students to link the particulate nature of matter to the other levels (macroscopic and symbolic levels). She found that the experimental group performed higher than the control group in all levels. This indicates that extra instruction that covers all levels can be effective in helping students to make connections between the three

levels on which chemistry is taught and understood. The method of dividing students into two groups i.e. the experimental and control groups will be employed in this study to check the effect of the remedial instruction to the experimental group as compared to the control group.

2.6 Language of Learning and Teaching (LOLT) in South Africa

Danili and Reid (2004) mentioned that the processes necessary for understanding chemistry are different from processes required to comprehend everyday events. The researcher is intending to find out how students struggle with the use of normal everyday words in the chemistry context. Some questions which will be addressed are whether language can be one of the hindrances when coming to information processing for students and also to come up with a constructive meaning in order to reach logical conclusion, and whether the current model (regarding the cohorts in this study) of instruction also affect students' abilities in learning chemistry. The following section will look at the issues of language in South Africa.

South Africa is one of the countries facing the dilemma of how to equip the majority of its population effectively with English as a second language. Although there are eleven official languages in South Africa, Afrikaans and English are the only languages with a developed academic literature used in both secondary school and higher institutions of learning. According to the 2011 census, only about 23% of South Africans speak Afrikaans or English as their first language (Statistics South Africa, 2012). In order to achieve educational and hence labour market success, the majority of South African students therefore need to become fluent in either English or Afrikaans. In reality, the majority choose to learn English rather than Afrikaans as the second language, given its status as a global language. More than 85% of the students in this study indicated that English was their second language, in which the first language was their mother tongue, although they did their matric subjects in English.

The majority of South African students do not speak English as their first language but are required to write their tests and examinations in English, in the higher institutions of learning. Most schools offer mother-tongue instruction in the first three grades, and then there is a transition to English as the language of instruction from the fourth grade until matric. Some schools use English and/or Afrikaans as the language of instruction from the first grade, as the material required for teaching exists in these languages, but the other languages might not have sufficient high quality instructional materials to address the issue of teaching in the language that suits each student. Tayler and Coetzee (2013) mentioned that in contexts where there are multiple home languages represented within the same classroom, it may be preferable to teach in English rather than any particular home language. The cohorts in this study are from various backgrounds and speak different mother tongues, although the majority of them are Setswana speaking. English should thus not be emphasized as the only language for instruction. Although the concept of teaching in various home languages is encouraged, some teachers may lack the proficiency in these languages, but I believe more can be done to improve the situation as suggested by some of the authors below that English must not be the “sole language of instruction”.

There is an on-going heated debate regarding the language of learning and teaching (LOLT) policies in South Africa. Questions remain on how the teaching of English should be introduced in schools, and when and how a transition to English as the primary language of instruction in non-language subjects should occur. The extent to which language contributes to students' performance is influenced by different factors such as historical disadvantage, socio-economic status, geography, the quality of school management and the quality of teachers (Tayler and Coetzee, 2013).

However, there are many in the South African education community who feel that language, and in particular the language policy, is a key determinant of education outcomes. On the

other hand, English is widely perceived to be the language of upward mobility and this leads to a preference for instruction in English from as early as possible (Tayler and Coetzee, 2013).

Dalvit, Murray, and Terzoli, (2009) argued about the myths of the use of Languages of Learning and Teaching (LoLT) in South Africa which involved both the public and academic debate about the following that;

- a. Only one language should be used
- b. The earlier one starts using English as LoLT the better;
- c. Using English as LoLT improves English proficiency.

They mentioned that language attitudes supporting the dominant role of English, both within the education system and in society as a whole, seem to indirectly contribute to the marginalisation of African languages. In a democratic country like South Africa, where language policy has to take all stakeholders into account, this has important implications. In this sense, English linguistic hegemony contributes to shaping important political decisions regarding the LoLT issue, which have real practical implications for speakers of an African language.

The use of multiple languages in the classrooms can also be encouraged rather than marginalizing the African languages, although English has been considered as universal language for communication. The South African education system needs to be improved and modified to fit its' diverse population's students' needs in any level of their studies which is guiding the language impact of cohorts in this study. Owen-Smith (2010) studied the language challenge in the classroom, in a multi-bilingual school in Johannesburg which had about eight or more home languages per grade. Their aim was for every child to develop two working languages, which are the common classroom medium (English) and the child's

particular home language. She mentioned that there are other problems attached to the single second-language medium which are also damaging. This included the parents' eagerness for the child to learn good English, and most parents easily fell into the trap of suppressing the spoken home language in the home, when in fact it needs to be actively promoted to remain vibrant in the face of an environment that says "only English is cool". This had resulted in parents only becoming aware of the costs of language suppression when the implications for communication within the broader family structure become evident and uneasy questions about identity and inferiority surface. She also said that if the child's self-esteem and self-confidence are undermined, this can contribute to the child's academic disadvantage. Owen-Smith (2010) described the alternative use of multi-bilingualism in the classroom, in which she mentioned the following points that;

- a. The multi-bilingual approach makes it possible for every learner to use the home language orally in the classroom via same-language peer interaction, alongside the common language, which is English in this regard. Together with a same-language partner, the learners can use their home languages to discuss explanations and to think through how to tackle problems.
- b. After introducing the activity in the common language, the teacher determines how and when home language learner-talks can be used and then wraps up the learning points for all in the common language (English).
- c. This puts a powerful teaching tool into the hands of a teacher faced with 11 or more languages, and who is herself/himself probably monolingual.
- d. By engaging learners in this way, the teacher moves beyond the constraints of teacher-centred methodology and makes good use of peers as well as all their languages as extra learning resources in the classroom. Non-official languages can also be used like this, as long as the learner has a similar language partner. No extra

teachers are required and a classroom is easily organised to make it possible for this kind of learner-talk to take place.

The arguments mentioned by Owen-Smith, are interesting and convincing, and this approach was tried in the primary school, in South Africa. It may be possible for the government to use the multi-bilingualism approach as a guiding tool to address the issues on how learning can be changed in higher education institutions. I believe that there are several ways in which their ability can be enhanced unlike considering English as the “thee language”.

2.7 Dimensions of Thinking

Whilst there are several taxonomies that describe intellectual skills and strategies Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, and Suther, (1988) provide a comprehensive framework. Marzano and colleagues identified the primary dimensions of thinking, which are metacognition, thinking skills, thinking processes, critical and creative thinking. This section will cover all Marzano’s dimension of thinking along with findings from other researchers.

2.7.1 Metacognition

This is often called strategic knowledge and it refers to the awareness of an individual’s own thinking processes while performing specific tasks i.e. what one knows and doesn’t know. This is an important factor in intelligence, learning and problem solving. Metacognition involves the planning that takes place before an individual’s thinking activity, regulation and evaluation of the appropriateness of thinking after completing the activity. This type of thinking includes strategies such as self-monitoring, advance planning, self-checking, questioning and evaluating (Johnson, 1997). Although metacognition is based on individual thinking processes, the current situation for most of the first years’ students is the challenge of being self-reliant. The majority still need guidance in the transition from a high school

setting to a university setting, so that they can improve their time management skills, perform individual tasks and do self-evaluation of the tasks on hand. Students need some strategies to find how to use their memories when faced with tasks requiring application of their knowledge. Some of the metacognitive strategies which the teachers or facilitators can use, given that student learning styles influence the way they process and perceive things, include mind mapping, illustrations, brainstorming, question and inquiry strategies, and communicating skills (Anderson, 2007).

Sirhan (2007) suggested that there are fundamental ideas that need attention which involve avoiding working-memory overload and processing of incoming information. Taber (2013a) postulated that people find ways to use their environment to enhance their memory span. For example, if a calculation is complex, students develop several methods such as writing down, using computers etc., to help them to come up with a strategic plan and temporarily store intermediate results externally. This strategy helps students to solve problems when they cannot keep all the information in their mind at once. Shore and Dover (2004) mentioned that this would help students to be more successful and have better metacognitive strategies. Taber (2013b) mentioned that although human beings have limited capacity to deal with novel information, their brains are effective in chunking together related information into complex structures (Baddeley, 2003). Taber mentioned that capacity is not related to the inherent nature of information but how it is perceived and related to existing knowledge.

Learners need to engage in a variety of metacognitive processes to monitor and control their learning, which include assessing the task at hand, evaluating their own strengths and weaknesses and monitoring various strategies. When students develop skills to engage these processes, they gain intellectual habits that not only improve their performance but also their effectiveness of learning (Nelson, 1992). Another challenge faced by students is the issue of time-tabling of their academic courses; they are often occupied from morning until afternoon

with lectures and practical sessions. This has resulted in their missing some of the important activities given by tutors and other extra help organised by the university which aims to develop their individual learning awareness and coping skills within the university. This type of extra-academic assistance needs to be improved and structured to best suit each student.

2.7.2 Thinking skills

Thinking skills are considered to be specific mental operations that are used in combination to achieve a particular goal.

Johnson (1997) indicated that the value of the specific thinking skills is limited unless we are able to combine them into larger thinking processes or strategies. Johnson mentioned that conceptual and operational definitions are needed before addressing the difficulty of developing intellectual skills. At the most basic level, intellectual skills are those mental operations that enable individuals to acquire new knowledge, apply that knowledge in both familiar and unique situations, and control the mental processing that is used to acquire and use knowledge, (Johnson, 1997). Marzano *et al.*, (1988) identified eight thinking processes that are used to gain knowledge and to apply it in daily life. They indicated that the first three which are concept formation, principle formation and comprehension are used primarily for learning purposes. The next four processes which are problem solving, decision making, inquiry and composition are mainly used to apply knowledge. The final process which is oral discourse is used during both knowledge acquisition and knowledge application.

2.8.4 Critical and creative thinking

The teaching of science involves much more than the mere transmission of factual information. Another important goal is teaching students to use basic facts and concepts flexibly so that they can deal with new situations, predict various consequences and solve

problems. Balfanz (1991) indicated that part of the problem is that education has been driven by assessment practices and philosophies that emphasize the importance of knowledge gain rather than knowledge application. Balfanz also mentioned that an effort to increase students' factual knowledge seems to impede the development of intellectual skills. Although the need for intellectual skills is of major importance, educators had difficulty in developing them. Taber (2013b) also indicated that the challenge faced by chemistry teachers is to allow students to experience something of the wonder of chemical science, by carefully supporting students to develop understanding of the subject.

Bloom's taxonomy had various classification of learning objectives for teachers to use to engage learning environments to improve high order thinking skills, which stimulates both creative and critical skills. Creative thinking skills are referred to as the ability to develop something new i.e. process of analysing to break down and understand information. Bloom's taxonomy divides learning objectives into three domains i.e. cognitive, affective and psychomotor, and it consider learning at higher levels being dependent on students having attained knowledge and skills at lower levels. This taxonomy can be used to guide teachers according to constructivists' views that learning should be based on encouraging students to reach higher levels. Whereas on the other hand it also focuses on the information processing ability of students that it can be influenced from lower to upper levels of the taxonomy. Sprenger (2008) divided explicit memory into semantic and episodic memory. Semantic memory involves students' ability to process and consciously retrieve the information presented to them, e.g. if students grasp meaningful scientific vocabulary, they can use higher cognitive skills such as synthesis and evaluation in Bloom's taxonomy. Sprenger's model was used during the intervention in such a way that it supports both the idea of information processing in the memory. It enhances thinking processes of students, and also focused on the constructivist views that the teacher guides students toward reaching conclusions.

The Bloom's taxonomy lower level domain was used as the guiding tool for the intervention programme in this study, to check the effect of the remedial instruction on the experimental groups. The domains in Bloom's taxonomy are summarized in Figure 2.3.

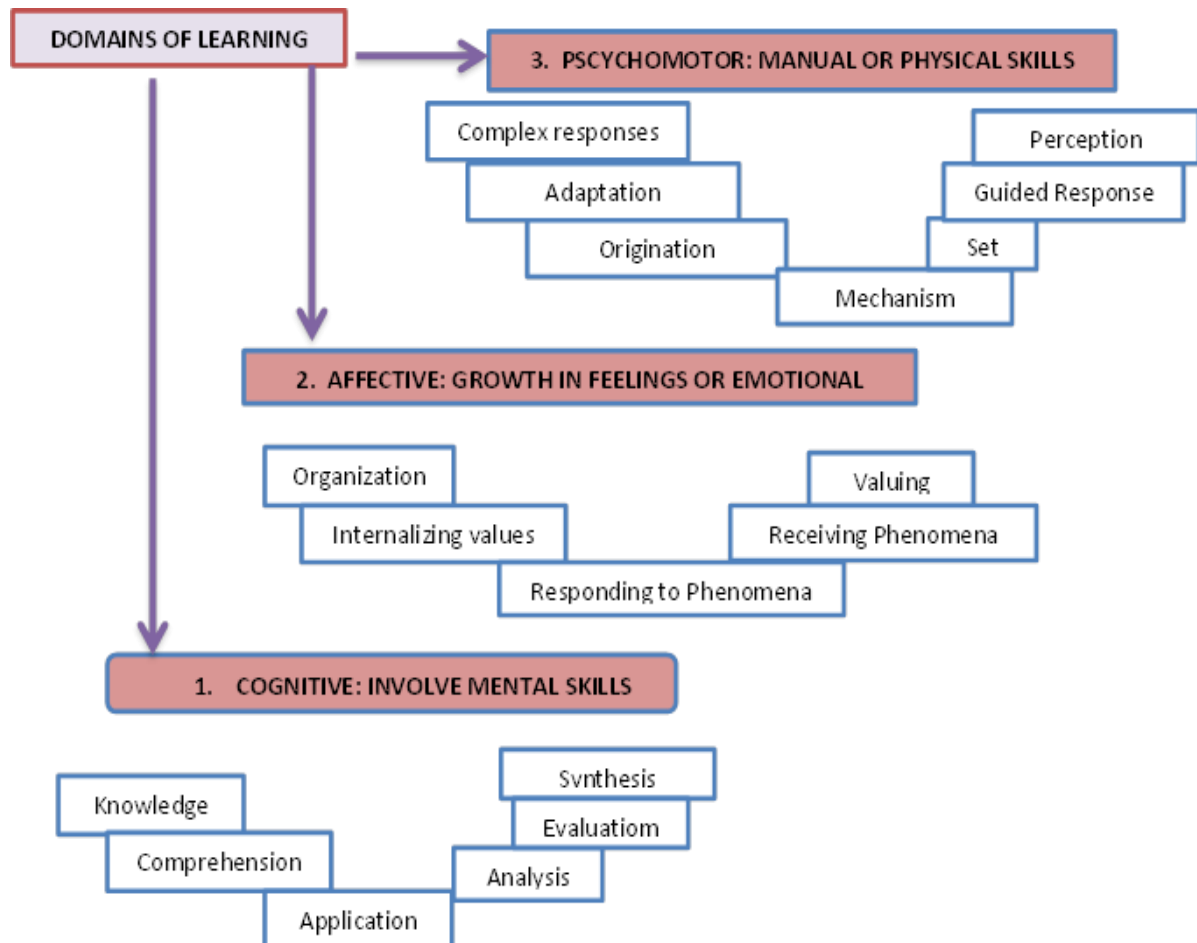


Figure 2. 3 Bloom's Domains of Learning

Marzano *et al.* (1988) indicated that both critical and creative thinking are unique processes as each individual engages in varying degrees of solving problems and making decisions. People differ in the way they solve problems, some use very creative approaches to arrive at a solution while others use little effort of creativity, and they also differ in the degree of critical thought used to reflect on the process needed to solve problems. Rajendran (2008) studied the higher order thinking skills, particularly creative and critical thinking skills. Higher order thinking skills require a person to apply new information or prior knowledge and manipulate the information to reach a possible answer in a new situation (Chang and Tan, 2005; Lewis

and Smith, 1993). Creative thinking can help an individual to be more innovative, have good creativity, and be more imaginative.

All students are capable of thinking, but most of them need to be encouraged, taught and assisted, which is in agreement with the constructivist view that the teacher must encourage students to come up with meaningful ways of mastering their learning. The information processing theory encourages students not to overload their working memory but rather develop strategies like chunking information into pieces and link it to the new incoming information. Thinking skills are fundamental in educational processes and are associated with the learning process. Resnick's (1987) study indicated that training students to think led to a positive impact on the development of their education. Their findings showed that there was an improvement in reading comprehension and average grades, as well as an increase in the ability to solve problems in mathematics and science.

2.9 Critical Aspects of learning

There are five critical aspect of learning, particularly taken from Marzano's dimensions of learning, which are described below which also incorporates some research findings regarding the use of them, particularly in students' learning, learning process and curriculum and assessment plans. They include;

- (a) Attitudes and perceptions;
- (b) Acquisition and integration of knowledge;
- (c) Extension and refinement of knowledge;
- (d) Meaningful use of knowledge;
- (e) Habits of the mind.

2.9.1 Positive attitudes and perceptions of learning (learning environment)

A student's attitudes and perceptions serve as filters that enhance or inhibit natural learning. Xu and Lewis (2011) define attitudes as emotional reactions of students towards science for example as being satisfactory and enjoyable. As students enter classrooms or other learning environments, motivation plays a critical role in guiding direction, intensity, persistence and quality of the learning in which they engage (Bandura, 1989; Ford, 1992; Marzano, 1992). For example, if students view the classroom as an unsafe and disorderly place, they are likely to learn little. Similarly if students have negative attitudes about their classroom tasks, they will probably put little effort into those tasks. Therefore, it is very important for a teacher to encourage acceptance, interaction and appreciation amongst students (Buchel, Coull, and Friston, 1999).

The majority of chemistry teachers aim to simplify the subject as much as possible for students in order to develop a meaningful learning environment which is in agreement with the constructivist views. Teachers make great efforts to develop innovative programs to engage students in the excitement of doing science (Xu and Lewis, 2011). The last thing educators want to see is students scoring high on standard tests, but thinking that science is boring or unpleasant, and never again using their scientific knowledge after it is no longer compulsory to do so. Science teachers have made great efforts to develop innovative programs with emphasis on problem solving, hands-on activities, real-world contexts and computer-aided instruction to engage students in the excitement of doing science. The intention is to create the curriculum that supports both gains in content knowledge and positive attitudes towards science.

An important educational goal is to foster students' positive attitudes towards learning science, so that they can be inspired to continue to develop scientific literacy throughout their

lives (Xu and Lewis, 2011). The tripartite structure which includes affection, behaviour and cognitive ability, is helpful in considering ways in which attitudes play a role towards science learning. Affection involves how people feel about the object which includes both good and bad feelings as expressed in the psychological activity or communication. Gardner (1975) defined affection as the emotional reactions of students towards science, which includes interest, satisfaction and enjoyment, whereas cognitive ability refers to how people think about the object that is knowledge, and their beliefs about properties of the object, which includes both favourable and unfavourable judgements.

Koballa and Crawley (1985) defined cognitive ability as a learned positive or negative feeling about science that serves as a convenient summary of a wide variety of beliefs about science. Behaviour refers to actions both positive and negative, with respect to the object as well as intentions to act. Xu and Lewis (2011) indicated that educators care mostly about the affective and cognitive aspects of attitude, especially focusing on students' viewpoints saying science is challenging (cognitive) yet interesting (affective).

Chan and Bauer (2014) found that, attitude and self-concept were collectively predictive of exam performance in chemistry. They proposed that chemistry achievement is based upon cognitive characteristics, affective experiences such as self-concept, attitude and other motivational and cognitive processes.

2.9.2 Acquisition and integration of knowledge

Students must be guided in relating new knowledge to what they already know, how to organize it and making it part of long term memory. Students come to class with knowledge and beliefs gained in other subjects and through daily life. This influences how they filter and interpret what they are learning. Students must develop not only the component skills and

knowledge necessary to perform complex tasks, they must also practice combining and integrating them (Anderson, Conrad, and Corbett, 1989).

Taber (2009) using a constructivist perspective, said that the learning process involves the following:

- i. An interpretation stage where the learner has to make sense of what is being taught, drawing upon the interpretative resources available;
- ii. A process of modifying existing knowledge to incorporate new learning.

Taber (2013a, 2014) mentioned that in some cases, internal resources may be supplemented by drawing upon external resources. Students can refer to their previous notes or a textbook to help them make sense of what has been taught. An example is when the teacher uses a dialogic approach to teaching and encourages students to share their ideas. This allows students to express their own interpretations and compare them with those of others.

The other factor that influences the learning process involves making changes to the internal conceptual structure which is the knowledge representations in the mind. Taber (2013a) described the “Ideal learning”, which allows existing conceptual structures that already integrate extensive aspects of prior learning to act as interpretive resources for new learning as shown in Figure 2.4

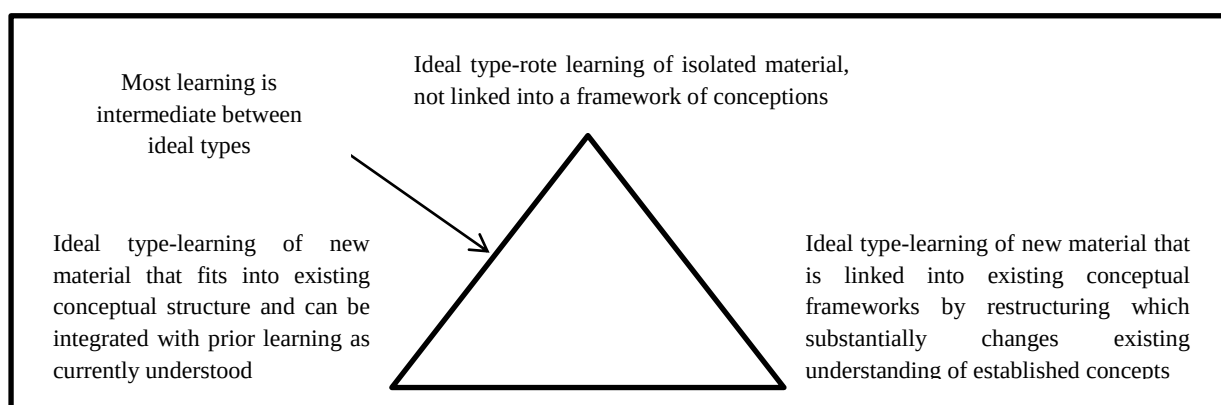


Figure2. 4 Ideal forms of learning (Taber 2013a)

The effective learner is often the one who has relevant prior learning that is already structured in a highly organised way, and can recognise how teaching can be related to what is already known (Taber, 2013b). The learner can chunk effectively to cope well with new incoming information presented in the classroom, only if teaching is planned to guide the learner to make links to prior learning.

The relationship between prior knowledge and general chemistry course performance has been well documented concerning the role of domain knowledge in comprehending new material (Shapiro, 2004). Seery (2009) indicated that in most situations, a student of higher prior chemistry knowledge would score better than a student of lower prior chemistry knowledge on measures of general chemistry achievement.

Pyburn, Pazicni, Benassi, and Tappin, (2013), studied the relationship between comprehension and performance in general chemistry by assessing students at university doing chemistry introductory courses. They used three predictor variables: prior chemistry knowledge, language comprehension ability and maths ability. They used the American Chemical Society (ACS) Toledo tests to assess prior knowledge in chemistry. These types of test are used for students' placement into chemistry introductory courses and contain three different sections with multiple choice questions. The first section tests students' ability in mathematics; the second section tests students' knowledge in general chemistry; and the third section tests the specific chemistry knowledge.

They also used the Scholastic Aptitude Test Critical Thinking Reading (SAT-CR) to measure language comprehension level of students. This SAT is a standardised exam taken by first year undergraduate students in the United States; it contains multiple choice questions that are categorized as either passage based reading or sentence completions.

The results of their study indicated that the students' ability in language comprehension level and mathematics ability were significantly correlated with their general chemistry performance, the results were closely related and in agreement with studies done by Glover, Kolb, and Taylor (1991) and Lewis and Lewis (2007, 2008).

2.9.3 Extension and refinement of knowledge

Students develop in-depth understanding through the process of extending and refining their knowledge, for example by making new distinctions, clearing up misconceptions and reaching conclusions. They analyse what they have learned by applying reasoning processes that will help them to extend and refine the information given. Marzano (1992) mentioned some examples of common reasoning processes which include:

- (a) Comparing – indicating how things are alike;
- (b) Classifying – showing how things can be organized;
- (c) Deductive reasoning – based on this rule what conclusions can be drawn that must be true.

Pyburn *et al.*, (2013) mentioned that deep comprehension of content is presumed to emerge from strategies that prompt the learner to generate inferences connecting what is being learnt to prior knowledge. These strategies include asking questions, answering questions, evaluating the quality of answers to questions, generating explanations and reflecting on the success of these strategies (Graesser, McNamara, and Van Lehn, 2005; McNamara, 2010).

Taber (2013b) suggested that it is important to limit what is presented to students “all at once”. I have also observed that if too many concepts are introduced all at once in a period of ninety minutes, this has resulted in some students being confused and losing focus along the way. Chemistry teachers need to give students time to make sense of the macroscopic

concepts and to become fluent in the technical terminology used to communicate these concepts as indicated in the triangle suggested by Johnstone (1991).

Another important tool which can assist students to develop independent learning is the use of concept maps. These are graphical tools which aid students in organising knowledge systematically and reflecting on their own understanding of the relevant topic (Yaman and Ayas, 2005). These maps can assist in facilitating meaningful learning by assisting memory search and help students to recall what they have learnt. Kinchin, Hay, and Adams, (2000) and Vanides, Yin, Tomita, and Ruiz-Primo, (2005) mentioned that the use of concept maps has benefits for both students and their teachers, as they help to recognise new relationships and new meaning, which they did not consciously have before.

2.9.4 Meaningful use of knowledge

The most effective learning occurs when students use knowledge to perform meaningful tasks. There are six reasoning processes which can encourage meaningful use of knowledge which are; problem solving, investigation, experimental enquiry, generating explanations, invention and systems analysis. There are certain tasks that can be performed by teachers to encourage students in the meaningful use of knowledge, such as oral discussions and composing. Oral discussions can be used to clarify and provide new insights into the topic of discussion, whereas composing can be used to create new ideas or solutions using known or existing information (Marzano *et al.*, 1988).

Taber (2013a) described this idea as scaffolding, which indicates that significant learning occurs when tasks are initially beyond the students' competence. The students' success can be supported by scaffolding the given task. Scaffolding includes structuring a particular task by providing hints and cues to simplify the activity for the learner. This implies that the teacher has to reduce the level of support, until the learners begins to master the task. Taber

(2011) mentioned that this scaffolding helps to develop an effective mental framework that allows the learner to organise and complete tasks without support. Encouraging the use of dialogic teaching methods allows students to explore new ideas, in terms of their own thinking, which relate to the formal teaching material (Mercer, Dawes, Wegerif, and Sams, 2004; Mortimer and Scott, 2003).

2.9.5 Productive habits of the mind

Effective learning develops powerful habits of mind that enable students to think critically, think creatively and regulate their behaviour. Ennis (1985) indicated several habits of the mind which are the main core for critical thinking: they are being clear and seeking clarity; being accurate; being open minded; and being sensitive to the level of knowledge and feelings of others.

2.10 Verbal Reasoning

Verbal reasoning refers to understanding and reasoning using concepts framed in words. It aims at ability to think constructively, rather than at fluency or vocabulary recognition. Burton, Welsh, Kostin, and van Essen, (2009) mentioned that verbal reasoning cannot be defined by a single coherent cognitive theory; rather, it represents several distinct thought processes that defy a precise definition. Verbal reasoning involves making meaning based on the information given, going beyond that information to a better understanding and applying verbal skills to new learning. Although speaking and listening are part of verbal reasoning, most formal verbal reasoning involves reading and writing. Also, while verbal reasoning sometimes refers to any task involving language understanding, it more often involves more complex thinking tasks, such as analysis, synthesis and evaluation of verbal information. At

its core, it is interactive reading that results in a change in background knowledge, attitudes and beliefs.

Cracolice and Busby (2015) mentioned that the standard curriculum assessment methods do not provide enough support for the development of students' scientific reasoning ability. They used the California grade twelve syllabus as an example that includes topics like atomic and molecular structure, chemical bonds, etc., which focuses only on teaching what may be considered as simplified general chemistry. They mentioned that some topics require fully developed scientific reasoning skills for students to be able to construct their declarative knowledge. It is therefore important for teachers to look beyond issues related to course content, as performance in general chemistry is not a function of what happens in the course, but to assist students to be independent thinkers and solve problems.

The state of knowledge of a student at the beginning of a course includes both declarative (i.e., knowing that) and procedural (i.e., knowing how) knowledge. Declarative knowledge is regarded as a predictive factor in students' performance and success, and intelligence might also be a cognitive characteristic used to measure success in the classroom. Individuals differ from one another in their ability to understand complex ideas and to engage in different forms of reasoning, to overcome the obstacles by taking thought. Neisser, Boodoo, Bouchard, Boykin, Brody, Ceci, Halpern, Loehlin, Perloff, Sternburg, and Urbina, (1996) mentioned that although these individual differences can be substantial, they are never entirely consistent. An individual's intellectual ability in terms of performance varies on different occasions, in different domains, and as judged by different criteria.

Cracolice and Busby (2015) mentioned that knowledge of topics that are associated with alternate conceptions can be another predictor of success in general chemistry. An alternate

conception is a mental construct held by an individual about the natural world which differs from that commonly held.

A diverse set of alternate conceptions are held by students entering general chemistry courses, and they are sometimes resistant to being modified by conventional instruction (Garnett, Garnett, and Hackling, 1995; Nakhleh, 1992). Students hold alternative conceptions about topics which are taught in the first semester of their introductory general chemistry course, such as understanding what a balanced equation represents, the mole concept, and thinking about atoms and molecules in general. Tytler (2002) mentioned that students' alternative conceptions can be a challenge for teachers to explain some chemistry concepts, because students could reject, accept or assimilate the concepts or ideas which are given by the teacher. This might be because they already had their own concepts which recognize a prior knowledge, and could be strongly held by students and sometimes they become difficult to change, which can also impede their reasoning abilities. In this study the students' reasoning abilities was tested with the understanding that they are supposed to use prior knowledge in answering questions requiring thinking and evaluation on content to reason logically.

Lawson (1992) mentioned that scientific reasoning ability also has been demonstrated to predict success in general chemistry. Lawson defined reasoning ability as the general disposition to consider alternative possibilities and the acquisition of accompanying hypothesis testing schemes that allow one to process evidence to choose among the alternatives. Scientific reasoning ability has been shown to be related to the ability to solve conceptual chemistry problems successfully (Bird, 2010; BouJaoude, Salloum, and Abid-EI-Khalick, 2004; Cracolice, Deming, and Ehlert, 2008).

Lewis and Lewis (2007) found that a pre-test of scientific reasoning ability predicted which students were at risk of not successfully completing their chemistry course, and Cracolice and Busby (2015) indicated that the development of students' scientific reasoning abilities should be a curricular goal for college preparatory chemistry courses. When instructors or teachers present the pre-packed conceptual curriculum to students as given in textbooks, they are actually taking away the opportunity for students to construct knowledge. They further indicated that if laboratory sessions and classroom environments are designed in a pre-digested conceptual system, this will have a serious effect on the students' thinking and can affect their ability to develop thinking skills. There is evidence that the introductory preparative course which only focuses on basic vocabulary, concepts and problem solving skills, seems to take away the opportunity for students to construct knowledge.

2.10.1 Analogical reasoning

Analogical reasoning is a method of processing information that compares the similarities between new and understood concepts and then uses those similarities to gain understanding of the new concept. It is a form of inductive reasoning because it strives to provide understanding of what is likely to be true, rather than deductively proving something as fact. This method can be used by both children and adults as a way to learn new information or as part of a persuasive argument. Analogical reasoning is based on the brain's ability to form patterns by association. The brain may be able to understand new concepts more easily if they are perceived as being part of a pattern. If a new concept is compared to something the brain already knows, it may be more likely that the brain will store the new information more readily (Gentner and Smith, 2012).

The study of the process and effectiveness of analogical reasoning is applied to many fields. Analogies demonstrate the likelihood of similarities rather than factually proving them. Most

science courses use analogical reasoning for coming up with new concepts. Scientists will often compare a proven scientific process with an unproven one to form hypotheses to base new research on. They may reason that because two processes are similar in one way, they are likely to have more things in common (Goswami, 1991).

2.10.2 Inductive reasoning

Inductive reasoning is a method of drawing a probable conclusion from an emerging configuration of data. In its purest form, this type of reasoning occurs by analyzing unbiased observations and discovering common patterns. When patterns repeat for an extended period of time, an analyst can logically predict that those patterns will continue to repeat. This inference, commonly known as generalization, can produce scientific deductions so probable that they are widely accepted as fact. Any theory involving generalization, however, can be disproved by one instance of inconsistency. One form of inductive reasoning is the application of certain circumstances to a likely cause. A simple instance of cause-and-effect inference would be the repeated discovery of dead livestock in an area where coyote tracks are also present. In many ways, the fallibility of inductive reasoning actually increases its strength as a scientific method. Sweeping statements often encourage thorough testing. It is likely, then, that any theory based on inductive reasoning will be challenged repeatedly (Burney and Mahmood, 2006).

2.11 Verbal Reasoning Theoretical Framework

Burton *et al.* (2009) designed a theoretical framework for thinking about verbal reasoning in higher education. This framework can be applied to measure the verbal skills needed to succeed in higher education. Their framework is based on general tests for admission of first year students into higher institutions of learning. Their emphasis is on verbal measures that

would produce independent students and on higher level skills such as critical reading. Verbal reasoning appears to involve many logically distinct cognitive operations and has several dimensions. This section describes some of the important aspects of their framework.

2.11.1 Critical reading

Burton *et al.*, (2009) considered critical reading to be the central or defining skill in verbal reasoning. Verbal reasoning and reading are not the same thing, but highly skilled critical reading is one of most useful aspects of verbal reasoning. They cited several studies of cognitive research that characterized reading as an active process that involves (Graesser *et.al.*, 1998):

- Constructing meaning;
- Evaluating differences between the text and the reader's existing knowledge and beliefs;
- Making inferences needed to fill gaps in understanding or clarity;
- Distinguishing between important and unimportant points in the text.

As the reader becomes more skilled, the reader tends to develop more comprehension skills that assist in proper reasoning capacity. Vocabulary has a strong relationship with measured reasoning or intelligence (Carroll, 1993; Sternberg, 1986).

2.11.2 Eight verbal cognitive operations important in higher education

Burton *et al.*, (2009) developed a schedule of eight categories of verbal cognitive operations. The first five form a sequence where prior operations must be completed before the next can take place, and they are also pre-requisites for categories 6-7, whilst category 8 can occur in all other operations. In their categories shown in Table 2.2 they included the words

“discourse”, which they used to refer to written texts in admission assessment, which can also be used for spoken, symbolic or graphical representations.

Table 2.1: Verbal Cognitive Categories (Burton *et.al.*, 2009)

Category	Clarification
1. Understand discourse	(a) Understand the meanings of words, sentences, and entire texts. Understand relationships among words and among concepts, and understand the structure of text. (b) Reason from incomplete data, inferring missing information or connections. (c) Select important points, distinguish major from minor or irrelevant points, summarize. (d) Use different reading strategies, depending on the text and one's purpose in reading; use multiple strategies for remembering.
2. Interpret discourse	(a) Analyse and draw conclusions from and about discourse. (b) Identify author's/speaker's perspective and assumptions. (c) Understand multiple levels of meaning (such as literal, figurative, author's intent, etc.).
3. Evaluate discourse	(a) Identify strengths and weaknesses. (b) Raise questions about the implications of discourse. (c) Consider alternative explanations. (d) Understand and balance multiple perspectives. (e) Appraise author's definitions and assumptions, evaluating sources for bias, self-interest, and lack of expertise.
4. Incorporate discourse with knowledge base and beliefs	(a) Evaluate differences between one's knowledge base and beliefs and discourse. (b) Integrate new information into one's knowledge base; revise/reorganize prior knowledge and beliefs based on discourse. (c) This might include discarding ideas that one judges to be wrong, but it might also include retaining knowledge and beliefs that are in conflict in recognition of the value of alternative viewpoints.
5. Create new understandings	(a) Move beyond the reception of knowledge to the use and application of knowledge. (b) Build upon discourse by integrating, elaborating, and transforming the content. (c) Synthesize information from a variety of sources. Incorporate understanding in a larger framework. (d) Compare, contrast, and integrate perspectives.

6. Seek and solve problems	(a) Identify areas that require further thought and research. (b) Develop possible explanations, and test them. (c) Apply knowledge and verbal reasoning strategies to new problem situations. (d) Use verbal reasoning and self-monitoring skills to set goals; plan and overcome obstacles in the course of problem solving.
7. Communicate	(a) Write, present, explain, define, persuade, teach, provide feedback to, and interact with people from a variety of communities of discourse. (b) Become fluent in the language and conventions of one's own discipline.
8. Monitor one's own comprehension, reasoning, and habits of mind	(a) Use multiple criteria to monitor comprehension while reading; change strategies when comprehension is unsatisfactory. (b) Use multiple strategies for overcoming obstacles in problem solving. (c) Strive to be well-informed, open-minded, flexible, and creative to maintain personal and professional integrity; and to maintain a broad perspective.

2.12 Conclusion

This chapter focused on the literature review based on information processing and constructivist theories that served as the theoretical background for this research. It also focused on descriptions of findings related to language and verbal reasoning difficulties in learning chemistry and also on important aspects of teaching and learning that can develop students' cognitive abilities. It also outlined some of the issues related to the medium of instruction in South Africa, particularly the motive to use English as the only medium of instruction, disregarding the use of other official languages. The next chapter will describe the methodology used in this study. It will include how the different stages of the investigation were carried out.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This research was conducted at North-West University (Mafikeng campus). The participants in this study were the chemistry students in the four year BSc program.. The sections below will describe the details of the course participants, research methods, the administration of the pre- and post-tests and the intervention programme (IP).

3.2 Course Participants

The participants in the study were the first year students of the four year BSc course. Two classes in the years 2013 and 2014 were used in order to get many participants. The total number of participants was 170 for the pre-test, and 79 for the post-test. The students came from diverse backgrounds and for most of them English was not their first language. All the students passed the South African Matric Certificate with a verdict indicating “Bachelors” in their certificates, which meant that they could register for the Bachelor’s degree at higher institutions of learning. But they could not register for BSc-degree programmes because of poor performance in English, mathematics and physical science, which were below the minimum 50% (level 4 in the CAPS document) required for the BSc-degree programme. The minimum level required for the above-mentioned subjects in the BSc-extended programme is 40-49% (level 3 in the CAPS document). The students in the four year degree program spend their first two years to complete the first year of the three year BSc degree. Then they enter the second year of the three year program.

The participants of the study signed consent letters for answering both the pre-test and post-test question papers. The letter indicated that the study was voluntary and that it would not have any effect on the evaluation of their academic performances (see Appendix A, pages 263-264). All participants were over 18 years of age.

3.3 Research Method

The quasi-experimental quantitative research method was employed which provides data that are quantifiable, objective and easy to interpret. The data produced was summarized in a way that allows for the generalizations concerning the performance of the groups used in the study. The design employed ensured that personal bias did not impact the data. Quasi-experimental designs require advanced statistical procedures and also may use surveys, interviews and observations. The design in this study employed the use of data to make inferences about the cohorts in the study by using inferential statistical analysis. This type of analysis examined the relationship between two samples used in the study, by looking for the significant differences between variables and the sample groups. Inferential statistics allowed the researcher to test hypotheses and generalize results to the population sample as a whole as shown below

a. Paired sample t-test:

H_0 : The means of the pre- and post-test is equal.

H_1 : The means of the pre- and post-test is not equal.

If the p-value is smaller than 0.05, we reject the null hypothesis and assume the mean of the pre- and post-test is not equal.

b. Independent sample t-test:

Groups:

H_0 : The means of the control- and experimental group is equal.

H_a : The means of the control- and experimental group is not equal.

If the p-value is smaller than 0.05, we reject the null hypothesis and assume the mean of the control- and experimental group is not equal.

c. Years:

H_0 : The means of the 2013 and 2014 groups are equal.

H_a : The means of the 2013 and 2014 groups are not equal.

If the p-value is smaller than 0.05, we reject the null hypothesis and assume the mean of the control- and experimental group is not equal.

d. Theoretically:

$H_0: \mu_1 = \mu_2$

$H_a: \mu_1 \neq \mu_2$

The example of the inferential statistical analysis used was the Paired-Sample t-test, which is used when the data sets are related in some way, in this regard both groups were the first year students doing chemistry introductory module (SFCM 171) within the BSc-extended programme. Dependent Samples t-test are used to compare two groups of scores and their means where for example in this research the relation is in a (pre-test):(post-test) research design. Because participants at the pre-test are the same participants at the post-test, in other words, the scores between pre- and post-test are dependent on each other. The test was applied to look at the pre-test and post-test scores, which belong to the same student tested. T-tests tell the researcher if the difference between two means is larger than would be expected by chance (i.e. statistically significant). The formula for the t-test is a ratio shown in figure 3.1. The top part of the ratio is just the difference between the two means or averages. The bottom part is a measure of the variability or dispersion of the scores.

$$t = \frac{\bar{X}_T - \bar{X}_C}{\sqrt{\frac{\text{var}_T}{n_T} + \frac{\text{var}_C}{n_C}}}$$

Figure 3. 1: t-test formula

The results of the t-test will tell if the difference between the means of the two groups (e.g. pre-test and post-test) is statistically significant, that is, whether this difference is larger than would be expected by chance. In the case of the intervention, if the dependent samples t-test was significant and the mean for intervention to the experimental group was higher at the post-test than at the pre-test, we might conclude that the intervention had a real, positive, effect on experimental groups. The t-test provides information about the results of the comparisons between the two means with the most important element of reporting the t-test based on its significance level. The significance level tells you if the difference observed between the means was greater than would be expected by chance (typically $p < 0.05$). If the p-value is < 0.05 there is a significant difference between the groups (95% confidence level), and if p-value is > 0.05 , it was taken that there is no significant difference. The strength of the association amongst the two groups was measured using effect sizes. The effect size is called Cramer's V-value. The guideline for the effect is as follows; ~ 0.1 small effect, ~ 0.3 medium effect and ~ 0.5 large effect.

3.4 Research design

The main steps in the study were:

- (a) Identification of non-technical/ non-conceptual words/ phrases/sentences in the recommended texts and reading material, and in tutorial questions, question papers and practical instruction sheets (in SFCM 171, the chemistry module for the first year

theory and practical course), whose meanings are important for learning, understanding and using chemical knowledge;

- (b) Identification of the types of verbal reasoning (both qualitative and quantitative) that are essential for learning effectively the recommended texts and reading materials;
- (c) Designing a pre-test question paper for testing understanding of the words/phrases/sentences and verbal reasoning skills identified above.

A copy of the pre-test question paper is shown in Appendix B (pages 262-273). There are few differences in the questions in the 2013 and 2014 papers. The 2014 paper is an improvement (analysis of the answers of students in the 2013 group suggested this improvement). The differences in the questions in the two question papers are indicated in the pre-test question paper.

- (d) Administration of the pre-test question paper to the first year students in 2013 and 2014.

The 2013 group of students was tested in October 2013 and the 2014 group was tested in May 2014. Two hours were allocated to answer the questions. Technicians in the chemistry department administered the tests to avoid any ethical problems because the researcher was also the students' lecturer.

- (e) Recording and analysis of student-student discussions of the pre-test question papers.

To get some information about students' verbal reasoning and information processing, they were asked to form small groups (of 5 or 6 students) and also discuss the question paper using any language. Their conversations (60-70 minutes) were recorded. Students were asked to form their own groups to make them more comfortable within their groups. Students were given the following instruction: "Look

at the pre-test question paper and discuss it amongst yourselves and indicate which questions gave you problems; record your conversations and state any confusion or problem encountered when trying to answer questions”.

- (f) Analysis of students’ answers to the pre-test questions and also study of the audio of student-student discussions to obtain information about students’ difficulties in language and verbal reasoning skills.
- (g) Development of a remedial instruction program for rectifying students’ difficulties and using it as an Intervention Program (IP) to train an “experimental group” of students.

The intervention program, for three weeks, was in April 2015, for a combined group of the 2013 and 2014 students (for 39 students). It was done after normal teaching hours and it encouraged active participation of students. Venue had Wi-Fi and Google search was encouraged to search for meanings of words, sentences and etc. Students worked in four groups of five students and each student was allocated a number (1-20). The intervention program used constructive views to guide students to construct their knowledge. The effects of the intervention program will be considered in chapter 5.

Remedial instruction was to rectify students’ difficulties identified in the pre-test.

The difficulties observed includes understanding of important meanings of non-technical words/phrases and inability to make conclusions from verbal statements. These difficulties were used by the researcher to design an intervention programme to guide students to develop their own learning styles, and use them to correct and somehow improve their language and verbal reasoning skills.

- (h) Testing the “experimental” group and the “control” group of students with a post-test.
- (i) Analysis of the results of the post-test and comparing it to those in the pre-test.

Students’ performances in the pre-test and post-test were analyzed using the SPSS Inc. (2015)/ IBM SPSS Statistics Version 22, Release 22.0.0, Copyright© IBM Corporation and its licensors. <http://www-01.ibm.com/software/analytics/spss/>. The total number of students was 170 for the pre-test and 79 for the post-test. This method verifies if there was a statistically significant association amongst the groups tested.

CHAPTER 4

PRE-TEST RESULTS AND THEIR ANALYSIS

4.1 Introduction

This chapter discusses in details students' performances in the pre-test questions with 74 first year students in 2013 and 96 first year students in 2014 were tested. The results attained for the 2013 and 2014 are also compared to check our impression that the quality of the students entering our university is increasing year by year. In this chapter the main objectives of each question are first stated and their solutions are given. Students' performances for the two groups of students are then analyzed and the SPSS method was used to compare their performances. For each question a table is given which summarizes the analysis.

Information attained from the audio are briefly presented and discussed at the end of the chapter

4.2 Question 1 (given in Appendix B, page 264)

4.2.1 Objective:

Question 1 tests understanding of some non-technical words/phrases which are used in chemistry. Lack of understanding of these words/ phrases can be expected to hinder learning and understanding of chemistry. This question involves the matching of words/ phrases in column A with words/ phrases in column B.

4.2.2 Solution: (*tested on both groups of students*)

Table 4.1a shows the correct solutions to the various parts of the question.

Table 4.1 a: Question 1 Solutions.

Column A (Words/Phrases)	Column B (Phrases/Statements)
1. Analyse	h. Examine or study something by breaking it down into parts.
2. Aqueous solution	d. A solution in which water is the solvent.
3. Combustion	f. Burning of a substance.
4. Compare	m. State similarities and differences.
5. Composition of a substance	g. Elements/ compounds present in a substance.
6. Constant	c. A quantity whose value does not change.
7. Deduce	r. To reason logically from given principles/facts.
8. Dissociation	e. Breaking up of a substance into simpler substances.
9. Emission	l. Release of something.
10. Excess reactant	j. More reactant than is needed for the reaction.
11. Fraction	a. A part divided by the whole.
12. Freezing point	n. Temperature at which a liquid becomes a solid.
13. Illustrate	q. To make clear by examples or pictures.
14. Percentage	i. Fraction multiplied by 100.
15. Ratio	p. The value of one quantity divided by another value of that quantity.
16. Simultaneous	k. Occurring at the same time.
17. Solute	o. The substance dissolved in a liquid to form a solution.
18. Variable	b. A quantity whose value can change.

4.2.3 Results:

The results to question 1 are given in table 4.1b.

- Column 1 indicates the question number;
- Column 2 indicates N (Frequency), which is the number of students who answered the questions correctly (cor), incorrectly (inc) and who did not attempt to answer (mis);
- Column 3 indicates the percentages of students who answered correctly (cor), incorrectly (inc) and who did not attempt to answer (mis);

- Column 4 concerns Pearson's Chi-Square test, with N_{valid} (showing the total number of students who answered (correctly and incorrectly) in both groups: it excludes those that did not attempt the question. It also shows the p-value which represents statistically significant association between the groups (2013 and 2014);

If the p-value is < 0.05 there is a significant difference between the groups (95% confidence level), and if p-value is > 0.05 , it was taken that there is no significant difference;

- Column 5 indicates the strength of the association amongst the two groups using effect sizes. The effect size is called Cramer's V-value. The guideline for the effect is: ~ 0.1 for small effect, ~ 0.3 for medium effect and ~ 0.5 for large effect.

Table 4.1 b: Question 1 Summary of Results

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
1.1	41	31	2	60	34	2	55	42	3	63	35	2	166	0.368	166	0.070
1.2	44	24	6	72	18	6	60	32	8	75	19	6	158	0.031	158	0.171
1.3	65	7		87	7		88	9	3	91	7	2	166	0.601	166	0.041
1.4	67	6	1	92	2	2	91	8	1	96	2	2	167	0.067	167	0.141
1.5	41	19	14	60	20	16	55	26	19	62	21	17	140	0.384	140	0.074
1.6	68	4	2	89	5	2	92	5	3	93	5	2	166	0.947	166	0.005
1.7	33	34	7	41	42	13	45	46	9	43	44	13	150	0.986	150	0.001
1.8	41	23	10	52	33	11	55	31	14	54	34	12	149	0.719	149	0.029
1.9	58	13	3	73	15	8	78	18	4	76	16	8	159	0.835	159	0.017
1.10	63	7	4	81	5	10	85	10	5	85	5	10	156	0.329	156	0.078
1.11	52	21	1	93	1	2	70	28	2	97	1	2	167	0.00	167	0.406
1.12	71	1	2	95	0	1	96	1	3	99	0	1	167	0.249	167	0.089
1.13	67	7		87	5	4	91	9		91	5	4	166	0.320	166	0.077
1.14	71	1	2	95		1	96	1	3	99		1	167	0.249	167	0.089
1.15	46	27	1	80	8	8	62	37	1	84	8	8	161	0.00	161	0.337
1.16	70	4		90	4	2	95	5		94	4	2	168	0.728	168	0.027
1.17	41	31	2	72	21	3	55	42	3	75	22	3	165	0.005	165	0.219
1.18	63	8	3	78	15	3	85	11	4	81	16	3	164	0.374	164	0.069
Ave	56	15	3	78	13	5	75	20	5	81	14	5	161	0.400	161	0.108

4.2.4 Discussion of Results:

This question required students to match some phrases with their meanings. Students' performance in many of the sub-questions were good. The average values for correct answers for all the questions tested was 75% for the 2013 and 81% for the 2014 group. However there were few variations in some of the questions. Students' performance in 2014 was better than in 2013 group. Table 4.1b shows that for four questions, out of eighteen tested, there is a significant statistical difference between the two groups with p-values less than 0.05, which are 1.2, 1.11, 1.15 and 1.17. The results for the questions that had significant statistical difference are;

- i. Question 1.2: Here the percentages of students in the 2013 and 2014 groups who answered correctly were 60% and 77% respectively. 33% who answered incorrectly matched the word “aqueous solution” with the phrase “the substance dissolved in a liquid to form a solution”. They did not know that aqueous solution means a solution in which water is the solvent.
- ii. Question 1.11: The percentages of students who answered correctly were 70% for the 2013 group and 97% for the 2014 group. The correct matching phrase for the word “fraction” was “a part divided by a whole”. 28% of the 2013 group who answered incorrectly matched the word “fraction” with the phrase “the value of one quantity divided by another value of that quantity”. Both phrases had the word “divided”; this may be the reason for students’ confusion.
- iii. Question 1.15: Students who answered correctly were 62% for the 2013 group and 84% for the 2014 group. The correct phrase was “the value of one quantity divided by another value of that quantity”. 37% of the 2013 students and 8% of the 2014 students matched the word “ratio” with the wrong phrase “a part divided by a whole”. Both phrases had the word ‘divided’ and this may have caused the confusion. Mistakes such as these indicate that students do not know the precise meaning of some important words such as fraction and ratio.
- iv. Question 1.17: Students’ performance was 55% for the 2013 group and 75% for the 2014. The correct matching phrase was “the substance dissolved in a liquid to form a solution”. 42% of the 2013 group and 22% of the 2014 group who answered incorrectly matched the word “solute” with the phrase “a solution in which water is the solvent”.

Question 1.7 was answered poorly by both groups of students. Only about 45% of them answered correctly. 45% of students who answered incorrectly matched the word “deduce”

with the phrase “breaking up of a substance”. This suggests that they did not understand the important word “deduce” and confused it with decompose or dissociate. This will be a serious limitation in their ability to answer questions that require the deduction of an answer.

Questions 1.1, 1.5 and 1.8, were answered better compared with the questions given above. The 2013 group scored around 55% and the 2014 around 60%. In all the other questions, the students’ performance was good, correct answers were in the range of 85-99%.

This question dealt with how students can “accurately remember” the meanings of words. The word “deduce” is used in everyday language and also in the scientific context.. The scientific context it “refers to making a conclusion by thinking about the known facts”. Many students matched the word incorrectly with “breaking up of a substance”. Two other important words which caused difficulty were words in which the students struggled with “ratio” and “fraction”. In daily language *fraction* is a small proportion of something (i.e. involves a division of a numerator and denominator), or a numerical quantity that is not a whole number, and ratio means the division of one number or quantity by another. Both words involved division in between, and students often do not distinguish between them. The poor performance of students may often be due their applying everyday meaning of the words than its meaning in the scientific context. This shows the difficulty in not understanding the meaning of non-technical words used in scientific contexts.

4.3 Question 2

- a. The volume of a gas is inversely proportional to its pressure. (*tested only on first year 2013 group*).
- b. The pressure of a gas is due to the continual bombardment of the walls of the containing vessel by the molecules. (*tested on both groups*).

- c. The percentage of oxygen in the air is 21% (*tested on both groups*).
- d. An electric current passing through a metal is due to the flow of negatively charged particles (electrons). (*tested on both groups*).
- e. The rate of diffusion of hydrogen gas is higher than that of oxygen gas because hydrogen molecules, being smaller, move at a faster speed. (*tested on both groups*).
- f. In a neutral atom, the number of electrons is equal to the number of protons. (*tested on both groups*).

4.3.1 Objective:

Question 2 tested the ability to differentiate between descriptive and explanatory statements. A descriptive statement gives experimental information about what is observed, whereas explanatory statements give reasons for the observation and why something is said to be true. In chemistry, explanations are given in terms of the particles present and their properties.

4.3.2 Solution:

- a. **Answer:** *This is a descriptive statement; it states the experimentally observed relationship between the volume and pressure of a gas.*
- b. **Answer:** *This is an explanatory statement. It gives the reason why there was pressure inside the vessel; pressure is caused by the collisions of molecules with the walls of the container.*
- c. **Answer:** *This is a descriptive statement, it merely states the percentage of oxygen in the atmosphere.*
- d. **Answer:** *This is an explanatory statement. Explanation is given in terms of the properties of particles present.*

- e. **Answer:** *This is an explanatory statement. It explains why hydrogen gas molecules diffuse at a faster rate, compared with oxygen gas molecules, in terms of the size of particles present.*
- f. **Answer:** *This is a descriptive statement. It merely states the composition of neutral atoms in terms of particles present.*

4.3.3 Results:

The results to question 2 are shown in table 4.2.

Table 4. 2: Question 2 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
2(a)	44	29	1				60	39	1							
2(b)	51	18	5	69	24	3	69	24	7	72	25	3	162	0.675	162	0.032
2(c)	62	12		83	12	1	84	16		86	13	1	169	0.625	169	0.037
2(d)	55	18	1	71	22	3	74	24	2	74	23	3	166	0.957	166	0.004
2(e)	56	13	5	76	18	2	76	17	7	79	19	2	163	0.588	163	0.042
2(f)	50	21	3	80	14	2	68	28	14	83	15	2	165	0.016	165	0.184
Ave	53	18	3	76	18	2	71	24	5	79	19	2	165	0.572	165	0.060

4.3.4 Discussion of Results:

A descriptive statement gives experimental information about what is observed, whereas explanatory statements give reasons for the observation and why something is said to be true. In chemistry, explanations are given in terms of the particles present and their properties. Statements (a), (c), and (f) were descriptive statements, whereas statements (b), (d) and (e) were explanatory statements. Though students were required to give reasons for their choice of answer, none of them attempted to give reasons. Question 2(f) have the p-value below 0.05 showing a significant difference amongst the groups. The statement was descriptive and

surprisingly this was expected from students to know that in a neutral atom the numbers of electrons are equal to number of protons. Students' performance were 68% for the 2013 group and 83% for the 2014 group.

The average students' performance was 71% for the 2013 group and 79% for the 2014 group. The word "describe" in normal everyday use requires someone to report, to tell or convey in words by writing something or saying it loud, whereas "explanation" refers to making something clear by giving more details or reasons to justify an action or event. These definitions are closely related to the scientific contextual use of the words, except that, in chemistry, explanations need to be given in terms of the particles present and their properties. Both groups performed well, and showed understanding of the words, although about 30% who failed could not recognize the difference in words. These are some of the meta-representational non-technical words that required students' ability to think by recalling and applying knowledge, as mentioned by Oyoo (2011). If students' language ability is not good, particularly those doing science in a second language, this can affect their ability to think clearly.

4.4 Question 3

- a. The density of a substance is the mass per unit volume. *(tested on both groups).*
- b. A litre of water is heavier than a litre of ethanol. *(tested on both groups).*
- c. The rate of diffusion of a gas is inversely proportional to the square root of its molar mass. *(tested on both groups).*
- d. Ice melts at 0°C . *(tested on both groups).*
- e. The rate of reaction increases in the presence of a catalyst. *(tested on both groups).*
- f. Silver is a better electrical conductor than copper. *(tested on both groups).*

4.4.1 Objective:

This question tested the ability to differentiate between qualitative and quantitative statements.

4.4.2 Solution:

- a. **Answer:** *This is a quantitative statement about the relationship between mass and volume which could also be expressed as an equation.*
- b. **Answer:** *This is a qualitative statement of an experimental fact. It cannot be expressed as an equation.*
- c. **Answer:** *This is a quantitative statement about the relationship between the rate of diffusion of a gas and its molar mass. It could also be expressed as an equation.*
- d. **Answer:** *This is a quantitative statement of an experimental fact.*
- e. **Answer:** *This is a qualitative statement. It cannot be given as an equation.*
- f. **Answer:** *This is a qualitative statement. It cannot be given as an equation.*

4.4.3 Results:

The results to question 3 are shown in table 4.3.

Table 4. 3: Question 3 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
3(a)	33	33	8	72	24		45	45	10	75	25		162	0.000	162	0.310
3(b)	14	49	11	66	29	1	19	66	15	69	30	1	159	0.000	159	0.495
3(c)	25	34	15	64	32		34	46	20	67	33		155	0.000	155	0.326
3(d)	32	33	9	46	46	4	43	45	12	48	48	4	157	0.544	157	0.046
3(e)	33	31	10	71	23	2	45	42	13	74	24	2	158	0.000	157	0.299
3(f)	44	20	10	79	16	1	59	28	13	82	17	1	159	0.000	159	0.253
Ave	30	33	11	66	28	2	41	45	14	69	29	2	158	0.091	158	0.288

4.4.4 Discussion of Results:

Quantitative statements can be converted into an equation but qualitative statements cannot. Though students were required to give reasons for their choice of answer, the majority of them did not attempt to do so. About five sub-questions had p-values below 0.05 with the 2014 group scoring higher than the 2013 group, whereas in part (d) both groups performed below 50% with the p-value above 0.05.

Statements (a), (c) and (d) are quantitative statements, whereas statements (b), (e) and (f) are qualitative. The performance of students in this question was poorer in the 2013 group than in the 2014 group. The 2014 performance was much higher in all sub-questions as compared to the 2013 group. The 2013 students' performances in sub-questions (a)-(e) ranged from 19-45% and in sub-question (f) it was slightly higher with 59%. The 2014 students' performances were above 65% in all sub-questions, except in sub-question (d) where the performance was lower with 48%. Part (d) includes a number and therefore would be expected to be answered better but it was in fact worse. These poor performances indicated that students had little knowledge on how to differentiate between the terms 'quantitative' and 'qualitative' statements.

The average students' performance for correct answers were 41% for the 2013 group and 69% for the 2014 group. The 2013 group scored lower than 50% in all parts except part (f), while for part (d) both the 2013 and 2014 groups performed below 50%;

- i. Statement (a) was a quantitative statement showing the relationship between density, volume and mass, the word "per" used in the phrase was referring to division. Students failed to apply their knowledge and this has resulted in them giving wrong answers.

- ii. Statement (b) had the lowest score by the 2013 group; the word “heavier” which means something that need effort to move, but not necessarily stating the weight (which is measurable). Students failed to recognize that the statement gave a narrative relation about which substance was heavier than the other, and that it is a qualitative statement.
- iii. In Statement (c) the 2013 group failed to link the relationship between the “rate of diffusion’ and the “square root of its molar mass” by using the word “inversely proportional” which could have given them a clue that this can be expressed in a form of an equation and that the statement is quantitative.
- iv. Statement (d) includes a value and a unit, thus it was expected that students would recognize that this was a quantitative statement. Surprisingly, the 2014 group performed worst in this part.
- v. Statement (e) was a qualitative statement, but the students failed to interpret the statement correctly, because it mentioned that the “rate of reaction increases in the presence of a catalyst”. This statement simply clarified that the speed at which a chemical reaction happens, is increased by the catalyst, but no amount is specified. The word “rate of reaction” might have caused difficulty or confusion as students may have thought that it represented a quantitative relationship.

These are some of the reasons why students performed poorly in the question because of misinterpreting non-technical words used in phrases. The 2013 group performed badly in all sections i.e., they thought that quantitative statements were qualitative and vice versa. This suggested that they did not understand the difference and merely guessed answers.

4.5 Question 4

- a. The temperature at which water boils is 100°C . (*tested on both groups*).

- b. Water dissociates to form H^+ and OH^- ions. (*tested on both groups*).
- c. Effusion is the escape of a gas through a small hole. (*tested on both groups*).
- d. The total mass of a system remains constant during a chemical reaction. (*tested on both groups*).
- e. Density is mass per unit volume. (*tested on both groups*).
- f. Matter consists of particles which are in constant motion. (*tested on the 2013 group only*).
- g. The volume of a gas (at constant temperature and pressure) is directly proportional to the amount of gas. (*tested on the 2013 group only*).

4.5.1 Objective:

This question tested whether some given statements were facts, laws, opinions, definitions or theoretical statements.

4.5.2 Solution:

- a. **Answer:** *This is a fact; this can be verified experimentally.*
- b. **Answer:** *This is a theoretical statement, in terms of the particles present.*
- c. **Answer:** *This is a definition; it defines effusion.*
- d. **Answer:** *This is a law; it is a law of conservation of mass.*
- e. **Answer:** *This is a definition; it defines density.*
- f. **Answer:** *This is a theoretical statement. It is kinetic molecular theory.*
- g. **Answer:** *This is a law; it states the relationship between the volume and the amount of a gas.*

4.5.3 Results:

The results to question 4 are given in table 4.4.

Table 4.4: Question 4 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
4(a)	63	11		93	3		85	15		97	3		170	0.006	170	0.212
4(b)	22	52		40	52	4	30	70		42	54	4	166	0.007	166	0.223
4(c)	56	18		75	20	1	76	24		78	21	1	169	0.706	169	0.029
4(d)	16	58		26	68	2	22	78		27	71	2	168	0.413	168	0.063
4(e)	33	41		45	50	1	45	55		47	52	1	169	0.767	169	0.023
4(f)	26	48					35	65								
4(g)	39	34	1				53	46	1							
Ave	36	37	1	56	39	1	49	50	1	58	40	2	168	0.380	168	0.110

4.5.4 Discussion of Results:

In this question sub-questions (a) and (c) were the only sub-questions in which students scored higher than 50%, with the 2013 in the range of 76-85%, and the 2014 from 78-97%. Whereas in the sub-questions (b), (d)-(f) the students' performances in both groups were below 50%. The p-values for the sub-questions (a) and (b) were below 0.05, and showed that there was significant statistical difference between the groups for correct answers. The effect was medium, with a larger number of the 2014 group scored higher as compared to the 2013 group.

The sub-questions in which there was a significant statistical difference and the students' performances were below 50% are described as follows;

- i. Statement (b) was a theoretical statement. The students' performance in this question was poor with 30% for the 2013 and 42% for the 2014 groups for correct answers. Students who answered incorrectly didn't recognize that theoretical statements need to be elaborated using the types of particles present. 70% of the 2013 and 54% of the

2014 groups of students failed the question. Amongst those who failed 46% of the 2013 and 24% of the 2014 groups of students indicated that the statement was a fact. 23% of both groups indicated that the statement was an “opinion”.

- ii. Statement (d) was the law of the conservation of mass. This meant that the mass of products was equal to the mass of reactants. Students’ performance in this question was very low for correct answers with 22% of the 2013 and 27% of the 2014 groups. 71% of the 2013 and 78% of the 2014 failed to answer the question correctly. Amongst those who had failed about 46% of the 2013 and 51% of the 2014 groups of students indicated that the statement was a “theoretical statement”. Also 9% of the 2013 and 7% of the 2014 groups of students indicated that the statement was a “fact”.
- iii. Statement (e) was the definition of density. Students’ performance was poor with 45% of the 2013 and 47% of the 2014 groups answering correctly. 51% of both 2013 and 2014 groups failed to answer the question correctly. Amongst those who had failed about 25% of 2013 group and 35% of the 2014 group indicated that this statement was a “law”, with 20% of the 2013 group indicating that it was a “fact”.
- iv. Statement (f) was a theoretical statement. Students’ performance was poor at 35% for the 2013 group. 65% of this group failed the question. The students who failed to answer the question correctly chose several wrong options, with 31% of them indicated that the statement was a “law” and 30% indicated it was a “fact”.

The average performances in this question for correct answers were 49% and 58% in the 2013 and 2014 groups respectively. This indicated that students struggled to understand the words used in phrases which can guide them to give the correct answers. For example in statement (d) which is a law, which has the words “total mass of a system is constant”, students failed to recognize that the word constant represents that the mass of reactants equals

the mass of the products. The assumption is that in the phrases given students did not apply enough mental effort and did not apply their thinking skills in connecting and picking guiding words within phrases.

4.6 Question 5

- (a) When a water sample is heated, temperature is absorbed and therefore the temperature will increase. *(tested on 2013 group. The correct answer to this question was given to the 2014 group of students to indicate to them how the other parts of the question need to be answered).*
- (b) When the temperature (T) of a substance is kept constant, it means that $T = 0$. *(tested on the 2013 group only).*
- (c) The percentage of girls in a class of boys and girls is 200. *(tested on both groups).*
- (d) The temperature of a water sample can be calculated using a thermometer. *(tested on both groups).*
- (e) Since 100 grams of atmospheric air contains 21 grams of oxygen, we can deduce that the percentage of oxygen in air is 21 grams. *(tested on both groups).*
- (f) The volume of a gas is 100 grams. *(tested on both groups).*
- (g) The number of molecules present in one mole of any substance is 6.0×10^{-23} *(tested on the 2013 group only).*

4.6.1 Objective:

This question tested the understanding of some words in sentences used to describe important concepts in science.

4.6.2 Solution:

(a) **Answer:** *The phrase “temperature is absorbed” is not correct, should be replaced by the phrase “heat is absorbed”.*

(b) **Answer:** *This is incorrect, T is not zero. When T is kept constant it means that change in temperature $\Delta T = 0$.*

(c) **Answer:** *Not correct, percentage should be equal to or less than 100. Or*

Answer: *The word “percentage” can be replaced by number.*

(d) **Answer:** *Not correct, the temperature is measured and not calculated; the thermometer is a measuring device.*

(e) **Answer:** *Not correct, the percentage is 21%.*

(f) **Answer:** *Not correct, the unit for volume is cm^3 (or dm^3 , etc) not grams. Or*

: Not correct, the word “volume” can be replaced by mass.

(g) **Answer:** *Not correct, the number of molecules cannot be less than one, 6.0×10^{-23} is less than one, should be 6.0×10^{23} .*

4.6.3 Results:

The results to question 5 are given in table 4.5.

Table 4.5: Question 5 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
5(a)	20	34	20				27	46	27							
5(b)	13	43	18				18	58	24							
5(c)	57	2	15	59	23	14	77	3	20	61	24	15	141	0.023	141	0.227
5(d)	35	23	16	66	21	9	47	31	22	69	22	9	145	0.005	145	0.217
5(e)	27	16	31	52	27	17	36	22	42	54	28	18	122	0.022	122	0.176
5(f)	31	21	22	46	40	10	42	28	30	48	42	10	138	0.676	138	0.211
5(g)	3	27	44				4	36	60							
Ave	26	24	24	56	28	12	36	32	32	58	29	13	137	0.182	137	0.208

4.6.4 Discussion of Results:

In this question the 2013 group performed below 50% in all sub-questions, except for 5(c) in which the score was satisfactory with about 77% higher than the score obtained by the 2014 group of 61%. The p-values for all sub-questions were below 0.05, this indicates that there was a significant statistical difference between the groups with medium effect, except for sub-question (f). This indicates that the 2014 group scored higher in most questions as compared to the 2013 group. But on average the 2014 group performed much better in the range of 54-69%, except for part 5(f) in which the score was below 50%. The sub-questions (i.e. (c)-(f)) in which both groups were compared, are discussed as follows;

- i. Statement (c) tested the understanding of the definition of “percentage”. Two options were correct i.e., (i) to replace the “200” with a number less than “100” or (ii) replace the word “percentage” with the word “number”. The students’ performances were varying in this question with 77% of the 2013 and 61% of the 2014 answering

correctly. 22% of the 2013 and 6% of the 2014 chose option (i), and 55% of both groups chose option (ii).

- ii. Statement (d) used the word “calculated” instead of the word “measured” because the thermometer is a measuring device. Students’ performances for correct answers were 47% of the 2013 and 69% of the 2014 groups. 31% of the 2013 and 22% of the 2014 failed to answer the question correctly.
- iii. Statement (e) was incorrect because percentage had no units, it cannot be given in grams. The performances in question for correct answers were 36% of the 2013 and 54% of the 2014 groups of students. 42% of the 2013 and 18% of the 2014 groups of students did not attempt to answer the question. Amongst those who answered the question, they circled the word “percentage” as the wrong word, and replaced it with the word “mass”. This could have been consistent with the unit given but it was not correct to say that there are 21g of oxygen in the air.
- iv. Statement (f) was incorrect because the unit for volume cannot be in grams as stated. Two options were correct i.e., (i) the unit for volume is cm^3 (or dm^3 , etc.) not grams, (ii) the word “volume” could be replaced by mass. Correct answers were given by 42% of the 2013 and 48% of the 2014 groups respectively. 15% of the 2013 and 33% of the 2014 groups chose option (i) i.e., gave several units for volume, and 27 % of the 2013 and 15% of the 2014 groups chose option (ii). 28% of the 2013 and 42 of the 2014 groups answered incorrectly. Amongst those who answered incorrectly, 20% of both groups circled the wrong word as “volume” and replaced it with the word “weight”, and 20% of the 2014 groups circled “grams” and replaced it by “ mol.dm^{-3} ”.

The questions which were tested only in the 2013 group are discussed as follows;

Statement (a) tested students' understanding of the concept temperature. In the sentence the word "temperature" should be replaced by the word "heat". The students' performance in this question was poor with the 2013 group scoring correctly at 27%. 46% failed and 27% did not attempt the question. 26% of those who failed replaced the word "absorbed" with "released" students could not distinguish between the words heat and temperature.

Statement (b) tested whether students recognize that when the temperature (T) of a substance is kept constant, it does not mean that $T = 0$ but that the change in temperature ΔT is zero. The 2013 students' performance was very poor with correct answers at 18%. 58% of the group failed to answer the question correctly.

Statement (g) was incorrect because the number of molecules cannot be less than one 6.0×10^{-23} is far less. The 2013 students' performance was very poor, with 4% of correct answers and about 60% did not attempt to answer the question. This could be due to non-recognition of the negative sign in the exponent. This may be due to the students thinking that the question tested factual knowledge; they did not recognize that the question tested the meaning of the number 10^{-23} .

The average students' performance in this question was very poor with 36% of the 2013 and 58% of the 2014 answering correctly. 32% of the 2013 and 29% of the 2014 groups respectively failed the question. This was a clear indication that most of the students could not pick up the language concepts which were wrongly placed within the sentences. In addition to this, most of the students who did not attempt to answer, wrote on the paper "I don't understand" or "I am confused" indicating perhaps that they did not understand the instructions. In sub-question (a) the students failed to notice that when something is heated the temperature rises but is not absorbed, only heat can be absorbed as stated in the phrase. In sub-question (b) when something is kept constant, it does not necessarily mean that its value

is equal to zero, it means to keep its value unchanged. In sub-question (d) in which we expected students to score higher, the 2013 group's performance was low, the word "calculated" was supposed to be replaced by the word "measured" since thermometer is a measuring device. In sub-question (d) the guiding word was percentage, students were expected to link the percentage with its symbol "%" which they failed to do so. In statement (d) the word "volume" has several units in which it can be expressed the students failed to realize that the word "grams" was not the proper unit for volume. These are indications that the students understanding of words to provide meaning and guiding them are minimal. If students were confused like they indicated in the answer sheet this shows that they were unable to recognise and organise the incoming information and make sense out of it, it was difficult for them to retrieve information from the long-term memory and make use of it in the work-memory. Also the way in which the non-technical words mentioned above were placed within the phrases caused the confusion in them giving wrong responses and some not attempting to answer the questions.

4.7 Question 6

- (a) The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a). *(tested on the 2013 group and given as a hint for the 2014 group). The answer to this part of the question was given in the question paper (as shown below) to indicate to the students as to how to answer parts (b) to (i).*
- (b) The concentration (c_A) of a solute A in a solution is defined as the amount (n_A) of A present per unit volume (v) of the solution. *(tested on both groups).*

- (c) The difference between the masses of two objects A and B is 4 grams, A having the larger mass. *(tested on both groups).*
- (d) The sum of m_A and m_B is 13 grams. *(tested on both groups).*
- (e) The mass fraction of A in the mixture of two substances A and B is 0.30. *(tested on both groups).*
- (f) The mass percentage of an element A in a compound is 30%. *(tested on both groups).*
- (g) The mass percent of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture. *(tested on the 2013 group only).*
- (h) The price of N chocolates is equal to the price of one chocolate multiplied by the number of chocolates. *(tested on the 2013 group only).*
- (i) The ratio of the number of the girls in a class to the number of boys is 0.30.

4.7.1 Objective:

This question tested the ability to convert quantitative statements into equations. Students had first to identify all the variable quantities in the statements and give symbols to them, secondly to write the equation relating the identified variables. Some answers were given to assist students; symbols were given for the different quantities in statements (a) and (b).

4.7.2 Solution:

- a. **Answer:** $R = \frac{k l}{a}$; *variables: R = resistance, l = length and a = area*
- b. **Answer:** $c_A = \frac{n_A}{v}$; *variables: c_A = concentration of A, n_A = amount of A and v = volume of solution.*

- c. **Answer:** $m_A - m_B = 4g$; *variables:* m_A = mass of object A, and m_B = mass of object B.
- d. **Answer:** $m_A + m_B = 13g$.
- e. **Answer:** $m_{A(fr.)} = \frac{m_A}{(m_A + m_B)} = 0.30$; *variables:* m_A = mass of A, m_B = mass of B,
 $m_{A(fr.)}$ = mass fraction of A.
- f. **Answer:** $m_A\% = \frac{m_A}{m_C} \times 100 = 30\%$; *variables:* m_A = mass of A, m_C = mass of compound
and $m_A\%$ = mass of percentage A.
- g. **Answer:** $m_A\% = \frac{m_A}{m_A + m_B + m_C} \times 100$; *variables:* $m_A\%$ = mass percent of a substance A,
 m_A = mass of A, m_B = mass of B, m_C = mass of C.
- h. **answer:** $P_N = P \times N$; *variables:* P_N = price of N chocolates, P = price of one chocolate,
 N = number of chocolates.
- i. **Answer:** $\frac{N_G}{N_B} = 0.3$; *variables* N_G = number of girls, N_B = number of boys.

4.7.3 Results:

The results to question 6 are given in table 4.6.

Table 4. 6: Question 6 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
6a	62	10	2				84	13	3							
6b	58	10	6	69	18	9	78	14	8	72	19	9	155	0.333	155	0.074
6c	52	17	5	72	15	9	70	23	7	75	16	9	156	0.491	156	0.053
6d	65	7	2	74	14	8	88	9	3	77	15	8	160	0.072	160	0.138
6e	14	50	10	57	32	7	19	68	13	59	33	7	153	0.000	153	0.407
6f	8	55	11	28	48	20	11	74	15	29	21	50	139	0.004	139	0.223
6g	38	21	15	63	20	13	51	29	20	66	21	13	142	0.052	142	0.144
6h	4	61	9				5	83	12							
6i		55	19					74	26							
Ave	33	32	9	61	24	11	45	43	12	63	21	16	151	0.159	151	0.173

4.7.4 Discussion of Results:

In this question the 2013 group was required to answer all the questions, whereas for the 2014 group some parts of the questions were omitted. Question 6(a) was given as a hint to the 2014 group, and question 6h and 6i were omitted. The results indicated that in this question the 2013 performed higher than the 2014 group in sub-question (b)-(d) and (f) with scores from 70-88% whereas the 2014 scored from 72-77%. In the sub-questions (e)-(g) the p-values were below 0.05 showing that there was a significant statistical difference in both groups, with the 2014 scored higher. The sub-questions (e) – (g) results will be discussed as follows;

- i. In statement (e) students' performances varied. The 2014 group scored the highest with 59% but the 2013 group scored 19%. 68% of the 2013 group failed to answer this sub-question correctly. Whilst 59% of the first year 2014 group were marked correct, about 41% of them managed to identify the variables and gave the correct equation, and about 18% only gave the equation.
- ii. In statement (f) both groups performed poorly below 30%, with 11% of the 2013 and 29% of the 2014 group answered correctly. Amongst the 29% of the 2014 group who answered the question correctly, 17% of them gave both the correct variables and equation, and 12% only gave the correct equation. 74% of the 2013 group failed to answer correctly and 50% of the 2014 did not attempt to answer the question.
- iii. In statement (g) the students' performances were 51% of the 2013 group and 66% of the 2014 group. Amongst the 2013 group who answered correctly, 33% of them failed to indicate the variable quantities and wrote the equation as $A\% = \frac{A}{(A+B+C)} \times 100$. In the 2014 group, 43% of them indicated both the correct variables and the equation, whereas 23 % wrote the equation only.

The following discussions are based on the questions given only to the 2013 group, and are as follows;

In statement (a) students' performance was good with 84% of the 2013 group answered correctly, although of those who answered correctly, 65% of them gave the correct relationship without including the constant 'k' in the equation.

In statement (h) the performance of the 2013 group was poor with only 5% answered correctly. 82% of the group answered this sub-question incorrectly, while 12% did not attempt to answer.

In statement (i) students' performance was very poor with none of the students answered correctly. 74% failed gave wrong answers and 26% did not attempt to answer the question. The performance in this question was very poor as compared to other questions.

The average students' performance was 45% in the 2013 and 63% in the 2014 group. The mistakes made by students arose from the fact that they did not follow the instructions; they failed to identify variable quantities and assign symbols related to them. The word "variable" refers to something that is not constant and can change, and is used in this way both in normal everyday language and in the scientific context. The words that were used to guide them in writing the correct equations were "inversely proportional", "directly proportional", "fraction", "percentage" etc. Some of these words were also used in question one, but the students failed to link them. This shows that sometimes we think that students understand words, but their use in phrases actually causes difficulty.

4.8 Question 7

4.8.1 Objective:

Question 7 tested students' ability to provide the meaning of the given words/ phrases and also state their opposites

4.8.2 Solution: (tested on both groups, with two words "Theoretical Statement" and "Reversible reaction" being omitted for the 2014 group tested. The 2014 group were only asked to give the opposite word). In column two students were required to give the meaning of a word or phrase given, indicated as a1, b1 etc. as shown in the results table. Column three required students to give the opposite word/ phrase as indicated in a2, b2 and etc. as shown in the results in Table 4.7a.

Table 4.7 a: Question 7 Solutions.

	Word/Phrase	Meaning of word	Opposite word/phrase
a.	Constant quantity	<i>Quantity which has a fixed value (it does not change).</i>	<i>Variable quantity.</i>
b.	Absorption of heat	<i>Takes in heat.</i>	<i>Emission of heat.</i>
c.	Proton donor	<i>Gives protons.</i>	<i>Proton acceptor.</i>
d.	Negative charge	<i>Has an extra electron.</i>	<i>Positive charge.</i>
e.	Theoretical statement	<i>Concerned with theories rather than facts.</i>	<i>Experimental statement.</i>
f.	Product of a reaction	<i>(End result of a reaction) what is formed in a reaction.</i>	<i>Reactant in a reaction.</i>
g.	Exothermic reaction	<i>Reaction where heat is released.</i>	<i>Endothermic reaction.</i>
h.	Reversible reaction	<i>Reaction that has ability to turn back to form reactants/products.</i>	<i>Irreversible reaction.</i>
i.	Oxidation	<i>Loss of electrons.</i>	<i>Reduction.</i>

4.8.3 Results:

The results to question 7 are summarized in table 4.7(b).

Table 4.7 b: Question 7 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
a.1	58	5	11				78	7	15							
a.2	33	23	18	53	23	20	45	31	24	55	24	21	132	0.170	132	0.105
b.1	39	25	10				53	34	13							
b.2	53	15	6	75	11	10	72	20	8	78	12	10	154	0.330	154	0.075
c.1	29	33	12				39	45	16							
c.2	38	29	7	60	26	10	51	39	10	63	27	10	153	0.145	153	0.112
d.1	10	51	13				13	69	18							
d.2	61	11	2				82	15	3							
e.1	5	47	22				7	64	29							
e.2	18	33	23	85	6	5	24	45	31	89	6	5	142	0.000	142	0.652
f.1	38	17	19				51	23	26							
f.2	60	3	11	71	11	14	81	4	15	74	11	15	145	0.273	145	0.084
g.1	62	7	5				84	9	7							
g.2	69	4	1	89	2	5	93	5	2	93	2	5	164	0.893	164	0.010
h.1	39	26	9				53	35	12							
h.2	44	27	3				60	36	4							
i.1	41	19	14				55	26	19							
i.2	66	1	7	90	2	4	89	1	10	94	2	4	159	0.284	159	0.082
Ave	42	21	11	75	11	10	57	28	15	78	12	10	150	0.299	150	0.160

4.8.4 Discussion of Results:

In this question the 2013 group was required to answers all questions whereas the 2014 answered the second part which required the opposite meaning of the words given, and those sections are sub-questions (a.2 to, c.2, e.2, f.2, g.2, and i.2). The students' performance in sub-questions b.2, f.2, g.2 and i.2 were satisfactory with the 2013 scored in range of 72-93% and the 2014 in the range of 78-93%. In sub-question c.2 both groups scored averagely with

51% for the 2013 and 63% for the 2014 for correct answers. But in sub-question a.2 the 2014 scored averagely with 55% and the 2013 group scored below with 45%. The only sub-question which has shown significant statistical difference was e.2, in which the 2014 group scored higher than the 2013 group with the marginal difference of 65% between the groups. The results for sub-questions a.2, c.2 and e.2 are discussed as follows;

- i. In sub-question (a.2) 45% of the 2013 and 55% of the 2014 groups gave the opposite word correctly. 31% of the 2013 and 24% of the 2014 respectively failed to answer the question correctly. Amongst the wrong answers, 15% of both groups gave the opposite phrase as “fluctuating quantity” and 6% of both groups as “unstable quantity”.
- ii. In sub-question (c.2) 51% of the 2013 and 63% of the 2014 groups gave the correct opposite word. 39% of the 2013 and 27% of the 2014 groups failed the question, and 20% of the 2013 group gave the incorrect opposite phrase as “an acid” and 10% of both groups as “electron gainer”.
- iii. In sub-question (e.2), 24% could give the opposite word, while in 2014, 89% could give the opposite word. However, about 45% of the 2013 group who failed to answer the question correctly, and gave the opposite phrases as “hypothetical statement” or an “opinion”. This indicated that they had some idea of the meaning, or how the word is used in everyday language.

The following discussions are for the questions tested only in the 2013 group. The students’ performance in the sub-question a.1 and g.1 were satisfactory with the score of 78% and 84% respectively. Whereas the results for sub-questions b.1, f.1, h.1 and i.1 the performance was average with the score just above 50%, and for sub-questions c.1 and d.1 the students performed poorly with the score below 40%. But for giving the opposite word the performance for sub-question d.2 were satisfactory with the score above 80% and sub-

question (h.2) on average at 60%. The discussions for sub-questions in which students performed poor and averagely are discussed as follows;

- i. In the 2nd phrase, sub-question (b.1), 53% of the 2013 group gave correct answers. 34% of the group failed to give the correct meaning of the word, while 13% did not answer. From those who failed 28% gave incorrect meaning as “endothermic”. This indicated that they had some understanding of the word i.e., they gave an example instead of a definition.
- ii. In the 3rd phrase, sub-question (c.1), students’ performance was very poor, with 39% of the 2013 answering correctly. 41% of the group failed the question, and 30% gave the incorrect meaning as “base” and 10% as “positive charge in the nucleus”.
- iii. For the 4th phrase, sub-question (d.1), the performance was very poor with 13% of the 2013 gave the correct meaning of the word, while 69% of them failed to answer correctly. Of those who failed, 30% gave the incorrect meaning as “anion”, 25% as a “negative ion” and 10% as an “electron”. Some of the students’ choices indicated that they did have an understanding of the word i.e., they gave an example instead of a definition. This was an indication that students may struggle to write the meaning in their own words, although they do understand the word, because they were able to give the correct opposite phrase. Those who failed gave the incorrect meaning as “anion” or “electron” and the incorrect opposite phrase as “cation” i.e., they gave an example instead of a definition.
- iv. For the 5th phrase, sub-question (e.1), the performance was very poor only 7% of the 2013 group could correctly define a theoretical statement. 64% of the group who failed to answer the question correctly.

- v. For the 6th phrase, sub-question (f.1) 51% of the 2013 group gave correct answers. 23% of the group gave the incorrect meaning as “the answer you got from multiplying” thus confusing mathematical product with product of reaction.
- vi. For the 8th phrase, sub-question (h.1) students’ performance was 53% in the 2013 group. 35% of the group failed to answer the question correctly and gave the incorrect meaning as “can be returned to its natural state”. In sub-questions (h.2) for giving the opposite phrase, the students’ performance was 60%. Amongst those who failed, about 24% gave the incorrect opposite phrase as “non-reversible” and 12% as “forward reaction”. Although these answers were not the correct words, they indicated some level of understanding of the word
- vii. For the 9th word, sub-question (i.1), the 2013 group scored correctly at 55%. 26% of the group failed to answer the question correctly, and about 13% of them gave the incorrect meaning as “increase of electrons” and 12% as “electron gainer” thus showing that they did not know the definition of oxidation.

The average students’ performance for the 2013 group indicated that students struggled to give the meaning of the words/phrases, with about 48% gave the correct answers. The average students’ performance for giving the opposite phrases was 66% for the 2013 and 78% for the 2014 groups. Some of the students knew the opposite phrases without really understanding their meanings. The words “constant”, “absorption”, “theoretical statement” were asked in the previous questions, but students failed to connect and recall them. The other words “donor”, “negative”, “product”, “exothermic” and “reversible” had been used throughout the students’ learning and it was expected that they would give the correct meaning, but some students failed to use their prior knowledge of how the words were used. This is another language barrier which affected the students’ ability to answer the questions correctly.

4.9 Question 8

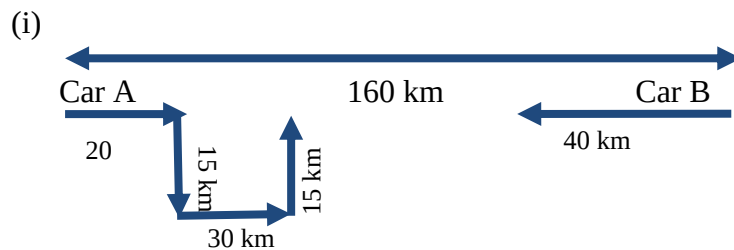
Two cars, 160 km apart on a main road, travel towards each other. The first car travels for 20km and takes a right turn and travels for 15 km. It then turns left and travels for another 30km, and then turns left again and returns to the main road. In the meantime, the other car travels 40 km along the main road.

- (i) Represent all the information given above as a diagram.
- (ii) What would be the final distance between the two cars?

4.9.1 Objective:

This question tested whether students can represent verbal information as a diagram (part i) and use the diagram to do a simple calculation (part ii).

4.9.2 Solution:



- (ii) From the above it can be seen that the distance (d) between cars A and B is

$$d = [160 - (20 + 30 + 40)] \text{ km} = 70 \text{ km}$$

4.9.3 Results:

The results to question 8 are given in Table 4.8.

Table 4.8: Question 8 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
8(i)	7	41	26	24	49	23	10	55	35	25	51	24	121	0.009	121	0.200
8(ii)	5	41	28	22	53	21	7	55	38	23	55	22	121	0.004	121	0.219
Ave	6	41	27	23	51	22	9	55	36	24	53	23	121	0.007	121	0.210

4.9.4 Discussion of Results:

In both sub-questions the p-values were below 0.05, although there was a significant statistical difference, both group's performances were poor with the score below 30%. The sub-questions results are discussed as follows;

- i. In sub-question 8(i) students were required to represent the information given as a diagram. Students' performance was very poor in both groups with 10% of the 2013 and 25% of the 2014 groups answering correctly. More than 50% of both groups gave incorrect answers. Most of them could not represent how car A moved in the diagram. Many of the students did not attempt to draw a diagram.
- ii. In sub-question 8(ii) students were required to use the information given to calculate the distance between the two cars. 7% of the 2013 and 23% of the 2014 groups respectively answered the question correctly. 55% of both groups answered the question incorrectly. The main reason for difficulty was that they failed to recognize that only the distances travelled by both cars towards each other should be added, instead they added all the values which both cars had travelled.

The average students' performance in both groups was very poor with 9% for the 2013 and 24% for the 2014 groups respectively giving correct answers. In this question students were given a task involving language understanding, which required them to analyse and

synthesise text in order to come up with an answer. This showed that students' ability to evaluate and sieve important information was minimal due to misunderstanding of the question, and their reasoning skills and ability to use diagrams to solve problems were below average.

4.10 Question 9

This question concerns the masses of 5 objects A, B, C, D and E. The mass of A is larger than the mass of B but is smaller than mass of C. The mass of D is smaller than the mass of A but is larger than mass of B. Object E has the largest mass.

- (a) Which object will have the smallest mass? (*tested on both groups*).
- (b) Arrange all the objects in order of increasing mass (i.e., start with the object that has the lowest mass). (*tested on both groups*).

4.10.1 Objective:

This question tested the ability to arrange qualitative verbal information (i.e., understanding of the words lowest and highest).

4.10.2 Solution:

- (a) **Answer:** Object B

- (b) **Answer:** 

: Or BDACE

4.10.3 Results:

The results to question 9 are given in Table 4.9.

Table 4.9: Question 9 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
9(a)	60	9	5	77	8	11	81	12	7	80	8	12	154	0.887	154	0.011
9(b)	38	26	10	61	24	11	51	35	14	64	25	11	149	0.110	149	0.123
Ave	49	18	7	69	16	11	66	23	11	72	17	11	152	0.499	152	0.067

4.10.4 Discussion of Results:

This question was tested on both groups, but for the 2014 group the masses of objects were included. In question 9(a) students were required to indicate which object had the lowest mass. The students' performances were good: about 80% of both groups answered correctly. In question 9(b) students were required to arrange all the objects in order of increasing mass i.e., from the lowest to the highest. Students' performances in this question varied from 51% of the 2013 to 64% of the 2014 groups. 35% of the 2013 and 25% of the 2014 answered the question incorrectly, while about 10-15% of students did not attempt the question.

The average students' performance was 66% for the 2013 and 72% for the 2014 groups. The p-values of both sub-questions were above 0.05, showing that there was no significant statistical difference between the groups. Those who failed did not realise that arranging the objects in a diagram would make the solution easier. This is suggested that when the diagram was drawn the students could easily position each object in its place, or rather give each object the value such that they can get the right order for arranging the objects properly. This showed that students need training on how to solve verbal statements by using diagram.

4.11 Question 10

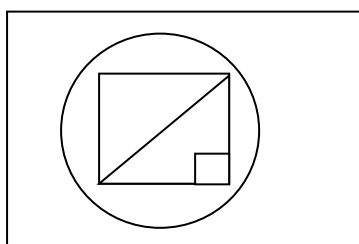
Draw a right-angled triangle inside a square and then enclose the square within a circle.

Finally draw a rectangle around all that you have drawn. (*tested on both groups*).

4.11.1 Objective:

This question tested the ability to follow instructions to draw a diagram from verbal statements. The drawing needs understanding of some words (e.g. right angled, triangle, square, circle and rectangle).

4.11.2 Solution:



4.11.3 Results:

The results to question 10 are given in Table 4.10 below.

Table 4.10: Question 10 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
(a)	47	22	5	47	38	11	63	30	7	49	40	11	154	0.058	154	0.145

4.11.4 Discussion of Results:

In this question there was a significant statistical difference, with p-value at about 0.05, with the 2013 group scored higher than the 2014 group. In this question 63% of the 2013 and 49%

of the 2014 groups gave correct answers. 30% of the 2013 and 40% of the 2014 groups gave incorrect answers, while 11% of both groups did not answer. Amongst those students who gave incorrect answers, 25% of both groups left out the rectangle and 15% of the 2014 group drew the different shapes separately.

The results obtained indicated that students still need further assistance on how follow instructions and interpret language used in verbal statements.

4.12 Question 11

Three men need ten hours to tile the floor of a house.

(a). Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer)

- | | |
|--|-------------------------------|
| (i) Men and floor of the house; | (ii) Three men and ten hours; |
| (iii) Number of tiles and surface area of the floor; | (iv) Number of men and time. |

(b). Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct).

- | | |
|----------------------------|------------------------------|
| (i) Directly proportional; | (ii) Exponential; |
| (iii) Quantitative; | (iv) Inversely proportional; |
| (v) Qualitative. | |

(c). How many hours will be needed by four men, working at the same rate, to tile the floor of this house?

(d). Write an equation that relates the time (t) needed and the number of men (N) employed, where k is a constant.

(e). Will 4 men need more or less time than 3 men to tile the floor of the house? (*Show how you reached the conclusion to your answer*).

4.12.1 Objective:

This question tested students understanding of various important aspects of inverse proportion reasoning.

4.12.2 Solution:

(a) (iv) Number of men and time. (*tested on both groups*)

(b) (iii) Quantitative and (iv) Inversely proportional (*tested on both groups*)

(c) Equation relating N_{men} and time (t) is $N_{\text{men}} = \frac{k}{t}$ (*tested on the 2013 group only*)

$$\text{from data given; } 3 = \frac{k}{10}$$

$$\therefore k = 3 \times 10 = 30$$

$$t = \frac{k}{N_{\text{men}}} = \frac{30}{4} = 7\frac{1}{2} \text{ Hours (four men will take less time to tile the house)}$$

(d) $N_{\text{men}} = \frac{k}{t}$ (*tested on the 2014 group only*)

(e) $N_{\text{men}} = \frac{k}{t}$ (*tested on the 2014 group only*)

$$a. \therefore k = N_{\text{men}} \times t$$

$$k = 3 \times 10 = 30$$

$$t = \frac{k}{N(\text{men})} = \frac{30}{4} = 7\frac{1}{2} \text{ Hours (four men will take less time to tile the house)}$$

4.12.3 Results:

The results to question 11 are given in Table 4.11.

Table 4.11: Question 11 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
(a)	33	38	3	49	40	7	45	51	4	51	42	7	160	0.404	160	0.064
(b)	48	23	3	66	26	4	65	31	4	69	27	4	163	0.593	163	0.041
(c)	30	20	24				41	27	32							
(d)				18	42	36				19	44	37				
(e)				82	3	11				85	3	12				
Ave	37	27	10	54	28	14	50	37	13	56	29	15	162	0.499	162	0.053

4.12.4 Discussion of Results:

In this question sub-question (a) and (b) were similar to both groups, where sub-question (c) was only asked in the 2013 group, which required them to indicate if four men will take less or more time, but were not given an equation or any clue. Whereas sub-questions (d) and (e) were given to the 2014 group, although this was split into two it asked the same question as in sub-question (c) given to the 2013 group. The variation lies on that part (d) gave the clue by asking about the equation which was supposed to be used in part (e) to check if four men will take less time or not. In both sub-questions (a) and (b) which were compared there was no significant statistical difference, and are discussed as follows;

- i. In sub-question 11(a) students were required to identify variable quantities in the given statements, the correct answer was the option (iv) number of men and time. 45% of the 2013 and 51% of the 2014 groups of students gave correct answers. 51% of both groups failed to answer the question correctly. Amongst those who failed,

about 45% of both groups chose the wrong option (ii) which was “three men and ten hours” confusing the variables and the quantities, although showing some understanding. This indicated that students struggled to understand what variable quantities are and this can have a serious impact throughout their learning.

- ii. In question 11(b) students’ performance was 65% for the 2013 and 69% for the 2014 groups. Students were required to indicate the relationship between the variables, and those who answered correctly 18% of the 2013 group and 21% of the 2014 group chose only one part which is “quantitative relationship”. Whilst 47% of the 2013 group and 48% of the 2014 group chose the other variable which is “inversely proportional” and none of the students chose both options.

In question 11(c) which was given only to the 2013 group, students were required to indicate whether four men can take less or more hours to tile the floor. The students’ performance in the 2013 group was very poor with only 41% of correct answers. 27% of the group failed to answer the question correctly and 32% did not attempt to answer the question. Student failed to recognize that they were supposed to write the relationship between the number of men and time taken to tile the house, thereafter do the calculation to prove if four man will require more or less time. Or use verbal reasoning or logical conclusion.

In question 11(d) students were required to write an equation which showed the relationship between men and time. 19% of the 2014 group gave correct answers. 44% of the group gave incorrect equations. This question was similar to question 6 (a) where the variable quantities were given to students as a clue, for them to write the equation. Although the clue was also given in this question, students’ performance was poor.

Question 11(e) which was given only to the 2014 group, was similar to question 11(c) tested only on the 2013 group. Students were required to indicate whether four men would take less

or more hours to tile the floor. Students' performance was good with 85% as compared to the 3% of the 2013 group in part (c). 45%, of those who answered correctly, gave only the answer without showing the calculation, and 40% showed the correct calculation. They could have used verbal reasoning and logic to give the correct answer without doing the calculation.

The average students' performance in this question was 50% for the 2013 group and 56% for the 2014 group. 37% of the 2013 group failed the question. This indicated that students need training in organising information, and also on how to use equations to solve verbal statements. The difficulty might be caused by the used of the words "variable physical quantities" which also caused problems in the previous questions; also understanding of the language in verbal statements can cause serious hindrance to reach logical conclusions.

4.13 Question 12

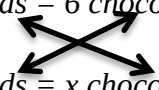
- (a) If six chocolates cost 42 rands, calculate the number of chocolates that can be bought for 30 rands.
- (b) State the variable quantities in this problem.

4.13.1 Objective:

This question tested the students understanding of important aspects associated with direct proportion reasoning.

4.13.2 Solution: (tested only on the 2013 group)

(a) $42 \text{ Rands} = 6 \text{ chocolates}$
 $28 \text{ Rands} = x \text{ chocolates}$



$$\therefore x \text{ chocolates} = \frac{28 \text{ Rands} \times 6 \text{ chocolates}}{42 \text{ Rands}} = \frac{168}{42} = 4 \text{ chocolates which can be bought from } 28 \text{ Rands}$$

Or this solution

Step 1

$$\frac{42}{6} = 7 \text{ rands, prize of one chocolate}$$

Step 2

$$\frac{28}{7} = 4 \text{ Chocolates can be bought from 28 rands}$$

(b) *Number of chocolates and price of chocolates*

4.13.3 Results:

The results to question 12 are shown in table 4.12.

Table 4.12: Question 12 Summary of Results.

	N (frequency)			Percentage		
	2013			2013		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	46	17	11	62	23	15
(b)	44	13	17	59	18	23
Ave	45	15	14	61	20	19

4.13.4 Discussion:

The students' performance in this question was average with the score just above the 60%, and the results for the sub-questions are discussed as follows;

- i. In the first sub-question (a), students were required to do calculations from the given statement. Their performance in this question was 62%. Amongst those who answered correctly, 47% of them did the correct calculations showing all the necessary steps, while 15% wrote the final answer without showing the calculations. 23% failed to answer the question correctly and also 15% did not attempt to answer.

- ii. In sub-question (b) students were required to identify variable quantities. The students' performance was 59% for correct answers. 18% of them answered the question incorrectly, while 23% of them did not answer the question.

The average students' performance in this question was 61% for correct answers. 40% of the students answered the question incorrectly, while about 20% did not answer. This indicated that students struggled to do calculations using direct proportion reasoning and also students failed to identify variable quantities. Students who can pick up the language concept quickly can be able to connect, recall accurately and apply their verbal reasoning skills, but those who struggle with language understanding tend to be affected and give wrong responses.

4.14 Question 13

(a) Gravel is insoluble in water. Which of the following statements will be correct?

- (i) The solubility of gravel in 100g of water at 20°C is 0g.
- (ii) The solubility of gravel in 100g of water at 100°C is 10g.
- (iii) The solubility of gravel in 100g of water at 50°C is 5g.
- (iv) The solubility of gravel in 100g of water at 20°C is 10g.

(b) The solubility of substance B at different temperatures is shown in the table below

Temperature	15°C	30°C	50°C	70°C
Solubility of B per 100g of water	40g	52g	60g	68g

Which of the following statements will be correct about substance B?

- (i) As temperature increases the solubility of substance B decreases.

- (ii) As temperature increases the solubility of substance B becomes zero.
- (iii) As temperature increases the solubility of substance B increases.
- (iv) As temperature increases the solubility of substance B stays the same.

4.14.1 Objective:

This question required students to select the correct alternative answer, given in multiple choice questions.

4.14.2 Solution: *(Tested on the 2014 group only)*

Answer: (a) (i) The solubility of gravel in 100g of water at 20°C is 0g

Answer: (b) (iii) As temperature increases the solubility of substance B increases.

4.14.3 Results:

The results to question 13 are shown in table 4.13.

Table 4.13: Question 13 Summary of Results.

	N (frequency)			Percentage		
	2014			2014		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	65	20	11	68	21	11
(b)	87	6	3	91	6	3
Ave	76	13	7	80	13	7

4.14.4 Discussion of Results:

The students' performance in both sub-questions varied, and the results are discussed as follows;

- i. In sub-question 13(a) students were required to select the correct option from the multiple choices. Students' performance was 68% for correct answers. 21% of the group failed to answer the question correctly, although a hint was given at the beginning of the phrase that "gravel is insoluble in water". Amongst those who answered incorrectly 16% chose option "ii" (The solubility of gravel in 100g of water at 100°C is 10g), and 5% chose option "iv" (The solubility of gravel in 100g of water at 20°C is 10g).
- ii. In sub-question 13(b) students were also required to select the correct option from the multiple choices. Students' performance was good with 91% giving correct answers.

The average students' performance was good with 80% for correct answers in the 2014 group. Both questions were multiple choices, and two words were used "insoluble" in 13(a) and "soluble" in 13(b). 30% failed to interpret the use of the word "insoluble" in question 13(a). These words are used in the most of their experimental activities. These are some of the non-technical words used in scientific context and normal everyday language, and failure to understand these words can hinder the students' effective learning.

4.15 Question 14

If heat is absorbed during the reaction $A \rightarrow B + C$, which of the following statements are correct for this reaction (more than one statement may be correct; circle the correct answers.)

- (a) Total energy of B and C will be greater than the energy of A.
- (b) Total energy of B and C will be equal to the energy of A.
- (c) The reaction will be exothermic.
- (d) The reaction will be endothermic.

(e) Heat will be evolved during the reverse reaction $B + C \rightarrow A$.

(f) The reaction $B + C \rightarrow A$ will be exothermic.

4.15.1 Objective:

This question tested the understanding and meaning of some important words in sentences.

4.15.2 Solution: (Tested on both groups)

Answers:

(a) Total energy of B and C will be greater than the energy of A.

(d) The reaction will be endothermic.

(e) Heat will be evolved during the reverse reaction $B + C \rightarrow A$.

(f) The reaction $B + C \rightarrow A$ will be exothermic.

4.15.3 Results:

The results to question 14 are shown in table 4.14.

Table 4.14: Question 14 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
(a)	30		44	27		69	41		59	28		72	57	0.201	57	0.137
(d)	55		19	61		35	74		26	64		36	116	0.241	116	0.129
(e)	14		60	10		86	19		81	10		90	24	0.260	24	0.126
(f)	33		41	52		44	45		55	54		46	85	0.463	85	0.095
Ave	33		41	38		58	45		55	39		61	71	0.291	71	0.122

4.15.4 Discussion of Results:

The students' performances in this question varied, and students were expected to elect options a, d, e and f, but from the results not all the parts were chosen by the students. Part (d) was the only sub-question in which the majority of the students chose correctly with the 2013 group performance satisfactory at 74% while the 2014 scored averagely with 64%. In parts (a) and (e) both groups scored below 50%, whereas in part (f) the 2014 scored on average just above 50% and 2013 scored below 50%. The following points were noted in some of the sub-questions;

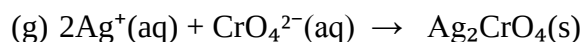
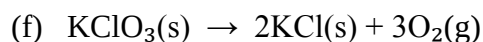
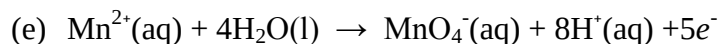
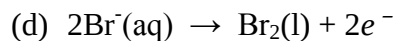
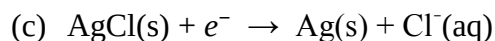
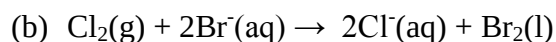
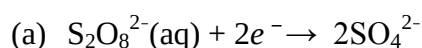
- i. In sub-question (d), 74% of the 2013 and 64% of the 2014 groups gave correct answers. Those who did not choose this option failed to recognize that in the forward reaction the statement indicated that "heat was absorbed" during the reaction $A \rightarrow B + C$, showing that it was an endothermic reaction. This sub-question was similar to question 7(g.2), and the students' performance was lower than in question 7(g.2). This was the only sub-question where students' performance were above 60%.
- ii. In sub-question (e), 19% of the 2013 and 10% of the 2014 groups gave correct answers. Students failed to link the forward reaction with the reverse reaction. It was indicated that heat was "absorbed" in the forward reaction therefore in the backward reaction heat will be "released".
- iii. In sub-question question (f) the performance was varying with 45% of the 2013 and 54% of the 2014 groups gave correct answers. In this sub-question students also failed to link the words "endothermic" which in this case referred to the forward reaction whereby heat was absorbed and "exothermic" which was the backward reaction whereby heat was released.

- iv. The students who did not answer the above sub-questions correctly chose option (b) (28% in 2013 and 23% in 2014) and option (c) (18% of both the 2013 and 2014 groups).

The average students' performances were poor with 45% for the 2013 and 39% for the 2014 groups for correct answers. 5% of those who answered correctly managed to choose all four options. This question indicated that students struggled with understanding of the meaning of some words used in sentences. They failed to link some of the words in the phrases given to the previous questions which had the same words, this is also an indication that if student put less mental effort, this tend to affect their ability to think precisely in order to recall and apply knowledge regarding these use of these words.

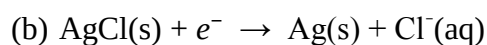
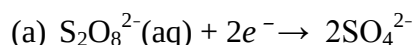
4.16 Question 15

A reduction reaction is defined as a reaction in which electrons are gained. Which of the following are reduction reactions (more than one statement may be correct; circle the correct answers)



4.16.1 Objective:

This question tested the understanding and application of an important definition (reduction reaction) used in chemistry.

4.16.2 Solution: (*Tested only on the 2013 group*)**Answers:****4.16.3 Results:**

The results to question 15 are shown in table 4.15.

Table 4.15: Question 15 Summary of Results.

	N (frequency)			Percentage		
	2013			2013		
	Cor	Inc	Mis	Cor	inc	Mis
(a)	39		35	52		48
(c)	33		41	45		55
Ave	36		38	48		52

4.16.4 Discussion of Results:

The students' performances varied and the definition of the word "reduction" was given and students were expected to choose the correct equation/s which indicates the gain of electrons. Two options were correct which were (a) and (c), 54% of the students chose option (a) and 45% chose option (c). Several incorrect options were chosen by students (option "d" with 60%, option "e" with 57%, and options "b" "f" and "g" with 20% respectively). Students failed to recognize that a "reduction reaction" involved the gain of electrons, which are

shown on the left side of the equation. The other wrong options (e.g. d and e), involved the reactions in which the electrons are on the right side of the equation, indicating that electrons are gained. Whilst the other wrong option (e.g. g) indicate the formation of a salt.

Students' performance in this question was below 50% and only 15% of the group managed to choose both options correctly. Even though the definition was provided at the beginning of the sentence, students were unable to link the equations with the given definition. This indicated that students struggled with understanding some definitions used in chemistry.

4.17 Question 16

Circle the *best* response to each question below

(a) Mass is to kilogram as volume is to

(i) Measuring cylinder.

(ii) Bottle.

(iii) Metre.

(iv) Litre.

(b) Barometer is to pressure as thermometer is to

(i) Heat.

(ii) Temperature.

(iii) Fever.

(iv) Weather.

(c) Square is to cube as circle is to

(i) Radius.

(ii) Sphere.

(iii) Round.

(iv) Ball.

(d) Oxidation is to reduction as exothermic is to

(i) Heat.

(ii) Endothermic.

(iii) Reaction.

(iv) Release.

4.17.1 Objective:

This question tested the analogical reasoning: relationship between words, and categorization of concepts.

4.17.2 Solution: (*Tested on both groups*)

Answers:

(a) iv-Litre

(b) ii-Temperature

(c) ii-Sphere

(d) ii-Endothermic

4.17.3 Results:

The results to question 16 are shown in table 4.16.

Table 4.16: Question 16 Summary of Results.

	N (frequency)						Percentage						Chi-Square test		Cramer's Value	
	2013			2014			2013			2014			N _{valid}	p-value	N _{valid}	v-value
	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis	Cor	Inc	Mis				
(a)	18	52	4	38	54	4	24	70	6	40	56	4	162	0.036	162	0.161
(b)	70	4		90	5	1	95	5	1	94	5	1	169	0.817	167	0.010
(c)	31	41	2	35	58	3	42	55	3	37	60	3	165	0.471	165	0.055
(d)	58	16		62	32	2	78	22		65	33	2	168	0.050	168	0.150
Ave	44	28	2	56	37	3	60	38	2	59	39	2	166	0.344	166	0.094

4.17.4 Discussion of Results:

The students' performances in this question varied, with sub-question (b) results satisfactory above 90%, and in sub-question (d) the 2013 group scored higher than the 2014 group with 78% and 65% respectively. The p-values for part (a) and (d) were below 0.05, this indicated that the 2013 group scored higher as compared to the 2014, with small effect. In sub-questions (a) and (c) both groups scored below 50%. The results for sub-questions in which students scored below 50% including sub-question (d) which are related to question 7 are discussed as follows;

- i. In question 16(a) the correct option was (iv) for litre (L). The students' performances were very poor with 24% for the 2013 and 40% for the 2014 groups gave correct answers. 70% of the 2013 group and 56% of the 2014 group failed to answer correctly. Amongst those who failed to answer correctly:
 - 42% in 2013 and 40% in 2014 chose the wrong option (i) (measuring cylinder: apparatus);
 - 17% in 2013 and 10% in 2014 option (ii) (wrong unit);
 - 13% in 2013 and 6% in 2014 option (iii).

They failed to identify from the first part which was gave them the relationship between the concepts that was needed (i.e., quantity and unit, not quantity and apparatus used to measure it).

- ii. In question 16(c) the word “circle” was supposed to be matched with the word “sphere”, and the students’ performances were very poor with 42% in 2013 and 37% in 2014 giving correct answers. 55% in 2013 and 60% in 2014 failed to answer the question correctly. Amongst those who failed:
 - 46% of both groups chose option (i) (part of a circle);
 - 9% in 2013 and 15% in 2014 chose option (iii) (attribute of a circle).

Although all groups covered the sections of three dimensional structures during the tests, it showed that students lacked skills in categorizing concepts.

- iii. In Question 16(d) the students’ performances were 78% for the 2013 group and 65% for the 2014 for correct answers. 22% of the 2013 and 33% of the 2014 failed the question, and chose the wrong option (iv). Those who failed related the word “exothermic” with the word “release”, they were not aware that the question asked for an opposite phrase. The word “exothermic” was also tested in question 7 where students were required to give the opposite phrase and meaning of the word, but the performance was better in question 7 than in this question.

The average students’ performance was about 60% for both groups for answering correctly. 40% of both groups failed the questions. These results showed that students struggled to find the relationship between words. This question tested the students’ ability to associate words by using prior knowledge and retrieving information. If a new concept is compared to something the brain already knows, it may be more likely that the brain will store the new information more readily. So the difficulty here was students’ inability to associate the word asked with what is already known in their mind.

4.18 Question 17

Dineo's test marks are twice that of Pule, and Pule's marks are a half that obtained by Tshiamo. Which of the following statements will then be correct?

- (i) Tshiamo has more marks than Pule.
- (ii) Dineo has more marks than Tshiamo.
- (iii) Tshiamo and Dineo have the same marks.
- (iv) Dineo has fewer marks than Tshiamo.

4.18.1 Objective:

This question tested the verbal reasoning ability to draw conclusions from given statements.

4.18.2 Solution: *(Tested only on the 2013 group).*

Answers:

- (i) Tshiamo has more marks than Pule.
- (iii) Tshiamo and Dineo have the same marks.

4.18.3 Results:

The results for question 17 are summarized in table 4.17.

Table 4.17: Question 17 Summary of Results.

	N (frequency)			Percentage		
	2013			2013		
	Cor	Inc	Mis	Cor	Inc	Mis
(i)	20		28	27		38
(ii)		19			26	
(iii)	43		20	58		27
(iv)						
Ave	31	19	24	42	26	32

4.18.4 Discussion of Results:

In this question two options were correct; option. (i) and (iii). 27% of students chose option (i) only and 58% option (iii) only, with 6% of them choosing both options correctly. 26% of the group chose the incorrect option (ii) and none of them chose option (iv). Some students who answered the question correctly tried to allocate marks to solve the problem in order to reach the right solution.

Students' average performances were 42% for correct answers, 26% of the group answered incorrectly and 32% did not attempt to answer the question. This suggests that students struggled to make conclusions from the given verbal statements. It required students to understand the meaning of certain information, which involves thinking and evaluating. This shows that the students were unable to understand words used in verbal statements.

4.19 Question 18

Dineo's test marks are twice that of Pule, and Pule's marks are a half that obtained by Tshiamo. If Pule obtained 40% which of the following statements will then be correct? (More than one statement may be correct; circle the correct answers)

- i. Tshiamo has two more marks than Pule.
- ii. Dineo's marks are double that obtained by Pule.
- iii. Tshiamo and Dineo both obtained 80%.
- iv. Dineo's marks are less than that of Tshiamo but double that of Pule.

4.19.1 Objective:

This question tested the verbal reasoning ability to draw conclusions from given statements

4.19.2 Solution: (*Tested only on the 2014 group*).**Answers:**

(ii) Dineo's marks are double that obtained by Pule.

(iii) Tshiamo and Dineo both obtained 80%.

4.19.3 Results:

The results to question 18 are shown in table 4.18.

Table 4.18: Question 18 Summary of Results.

	N (frequency)			Percentage		
	2014			2014		
	Cor	Inc	Mis	Cor	Inc	Mis
(i)		13			14	
(ii)	64		19	67		20
(iii)	75		13	78		14
(iv)		8			8	
Ave	69	11	16	72	11	17

4.19.4 Discussion of Results:

This question tested the similar aspect as in question 17 for the 2013 group, but in this question a hint was given by including Pule's marks. The two options were correct i.e., (ii) and (iii). 67% of the students chose option (ii) only, and 78% chose option (iii) and about 58% of them managed to choose both options correctly. Those that did not choose the above two options, chose wrong options, with 14% of them chose option (i) and 8% of them chose option (iv).

Students' average performances were good in this question with 73% for correct answers.

This question was similar to question 17 given in 2013, but with Pule's marks included. The

2014 group scored higher than the 2013 group. Those who answered incorrectly, failed to recognize that in both questions, Tshiamo and Dineo's marks were equal, whereas Pule's marks were half those obtained by both Tshiamo and Dineo. This suggest that students need training on how to draw conclusion from the information given statement.

4.20 Question 19

A sugar solution contained in a vessel is diluted by adding water. Consider the following statements and state whether they are correct or not. Briefly explain your answers.

- (a) Mass of sugar in the solution will remain constant.
- (b) The mass of the solution will increase.
- (c) The volume of the solution will increase.
- (d) The concentration of the sugar in the solution will decrease.
- (e) The concentration of the sugar in the solution will increase.

4.20.1 Objective:

This question tested students on comprehension of simple concepts that are important in chemistry by applying laws and equations.

4.20.2 Solution: *(Tested only on the 2013 group).*

- (a) **Correct.** From the law of conservation of mass, the mass of the sugar will remain the same.
- (b) **Correct.** The extra water will contribute extra mass.
- (c) **Correct.** The volume is increased because more water was added.
- (d) **Correct.** From the equation $c = \frac{n}{V}$ when volume increases concentration will decrease.

(e) **Incorrect.** From the equation $c = \frac{n}{V}$ when volume increases concentration will decrease.

4.20.3 Results:

The results to question 19 are shown in table 4.19.

Table 4.19: Question 19 Summary of Results.

	N (frequency)			Percentage		
	2013			2013		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	22	23	29	31	30	39
(b)	23	23	28	31	31	38
(c)	26	20	28	35	27	38
(d)	33	16	25	45	21	34
(e)	31	13	30	42	18	40
Ave	27	19	28	37	25	38

4.20.4 Discussion of Results:

The students' performance in this question was very poor with the score for all the question below 50%, and the results for each sub-question are discussed as follows;

- i. In part (a) students were required to indicate whether the mass of the sugar in the solution would remain constant. The students' performance was poor with only 31% of them giving correct answers and 30% of them answered the question incorrectly. Students failed to recognize that the mass of sugar in the solution does not change. About 40% of the group did not attempt to answer the question.
- ii. In part (b) the students were required to indicate whether the mass of the solution would increase. Students' performance was also very poor in this question with 31% of correct answers. 31% of the group answered incorrectly and 38% of them did not

attempt to answer the question. Students failed to recognize that it was true that the mass of the solution increased because more water was added to the solution.

- iii. In Part (c) students required to indicate if the volume of the solution would increase. The students' performance was very poor with 35%. 27% answered incorrectly and 38% of the group did not attempt to answer the question. Surprisingly, students failed to recognize that adding more water was increasing the volume of the solution.
- iv. Part (d) required students to indicate whether the concentration of sugar had decreased. The performance was poor with 45% of correct answers, 21% gave incorrect answers and 34% did not attempt to answer the question. Instead of applying the equation that relates concentration and volume which is $C = \frac{n}{V}$, to assist them in drawing the conclusion, the students tried to reason without giving any relationship between the volume and concentration. Students failed to show that, according to the equation stated above; when the volume increases the concentration will decrease.
- v. Part (e) was the opposite of part (d) and required students to indicate whether the concentration of sugar has increased, for the same reasoning as in part (d), this statement is incorrect. The performance was poor with 42% of correct answers and about 18% incorrect answers. 40% of the group did not attempt to answer the question. They did not apply the equation that relates concentration and volume which is $C = \frac{n}{V}$, to assist them in drawing the conclusion. The equation shows that the statement was wrong and the concentration of sugar did not increase.

The average students' performance were 37% for correct answers, 25% for incorrect answers, and 38% of them did not attempt to answer the question. Students need assistance in solving some chemistry problems by using equations and applying laws.

4.21 Question 20

A student pours 1.5 ml of vinegar in a beaker, and dilutes it with 50 ml of distilled water.

Consider the following statements and state whether they are correct or not.

- (a) Mass of vinegar in the solution will remain constant.
- (b) The volume of the solution will increase.
- (c) The concentration of vinegar in the solution will decrease.
- (d) The concentration of vinegar in the solution will increase.

4.21.1 Objective:

This question tested the comprehension of some simple concepts that are important in chemistry.

4.21.2 Solution: (Tested only on the 2014 group).

- (a) **Correct.** From the law of conservation of mass, the mass of vinegar remains the same.
- (b) **Correct.** The volume increased because more water was added.
- (c) **Correct.** From the equation $c = \frac{n}{V}$ when volume increases the concentration will decrease.
- (d) **Incorrect.** From the equation $c = \frac{n}{V}$ when volume increases the concentration will decrease.

4.21.3 Results:

The results to question 20 are shown in table 4.20.

Table 4.20: Question 20 Summary of Results.

	N (frequency)			Percentage		
	2014			2014		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	55	33	8	57	35	8
(b)	83	6	7	87	6	7
(c)	71	18	7	74	19	7
(d)	82	7	7	86	7	7
Ave	73	16	7	76	17	7

4.21.4 Discussion of Results:

This question which was tested only in the 2014 group, it tested students on comprehension of simple concepts that are important in chemistry by applying laws and equations like question 19. The results are discussed as follows;

- i. In part (a) students were required to indicate whether the mass of vinegar in the solution would remain constant. 57% of the group gave correct answers, and 35% failed the question. Students failed to recognize that the mass of vinegar in the solution does not change.
- ii. In part (b) students required to indicate whether the volume of the solution would increase. The students' performance was good with 87%.
- iii. In part (c) students required to indicate whether the concentration of vinegar would decrease. The performance was satisfactory with 74%, while 19% answered incorrectly. Instead of applying the equation that relates concentration and volume which is $C = \frac{n}{V}$, to assist them in drawing the conclusion, students tried to reason without giving any relationship between the volume and concentration. Students failed to show that, according to the equation stated above; when the volume increases the concentration will decrease.

- iv. Part (d) required students to indicate whether the concentration of vinegar would increase, which was opposite of 20(c). The performance was again good with 87%, and 7% answered incorrectly. They did not apply the equation that relates concentration and volume which is $C = \frac{n}{V}$, to assist them in drawing the conclusion, the students tried to reason without giving any relationship between the volume and concentration. Students failed to show that according to the equation stated above that when the volume increases the concentration will decrease. The equation shows that the statement was wrong and the concentration of vinegar did not increase.

The average students' performance was 76% for correct answers and 17% of the group answered incorrectly. Although this question was similar to question 19 tested on the 2013, the performance in the 2014 group was much better compared to the 2013 group. This was also suggests that students need proper training on solving some chemistry concepts by applying laws and equations.

4.22 Question 21

The mass fraction of oxygen in a compound is 0.20. Calculate the mass of

- (a) oxygen that will be present in 50 g of the compound.
- (b) the compound that will contain 10 g of oxygen.

4.22.1 Objective:

This question tested whether students use the defining equation or verbal reasoning to solve a problem involving mass fraction.

4.22.2 Solution: *(Tested only on the 2013 group)*

$$(a) \text{ Mass fraction} = \frac{\text{Mass of Oxygen}}{\text{Mass of Compound}}$$

$$0.2 = \frac{\text{Mass}_{\text{Oxygen}}}{50 \text{ g}}$$

$$\therefore \text{Mass}_{\text{oxygen}} = 0.2 \times 50 \text{ g} = 10 \text{ g}$$

$$(b) \text{ Mass fraction} = \frac{\text{Mass of Oxygen}}{\text{Mass of Compound}}$$

$$\text{Mass of compound} = \frac{\text{Mass}_{\text{Oxygen}}}{\text{Mass}_{\text{fraction}}}$$

$$= \frac{10 \text{ g}}{0.2} = 50 \text{ g}$$

4.22.3 Results:

The results to question 21 are shown in table 4.21.

Table 4.21: Question 21 Summary of Results.

	N (frequency)			Percentage		
	2013			2013		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	15	27	32	20	37	43
(b)	5	27	42	7	36	57
Ave	10	27	37	13	37	50

4.22.4 Discussion of Results:

The students' performance in this question was very poor within the range of 7-20% for answering correctly. The results for each sub-question are discussed as follows;

- i. In part (a) students were required to calculate the mass of oxygen from the given mass of the compound. The students' performance was very poor with 13% of correct answers and 37% of incorrect answers. 50% of the group did not attempt to answer the question. From those who failed 35% of them did not start with the equation that

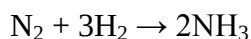
indicates the relationship between the fraction and mass of compound, while 2% tried but gave the wrong equation.

- ii. In part (b) students' performance was also very poor with only 7% of correct answers. 57% of the group did not attempt to answer the question. 45% of those who did not attempt to answer the question wrote "confused" next to the question asked.

The average performance in this question was 13% for correct answers and 37% failed to the question. 50% of the group did not attempt to answer the question. This indicated that students struggled to solve problems by using verbal reasoning or the defining equation.

4.23 Question 22

Consider the following reaction, and answer the questions which follow.



- (a) How many moles of hydrogen are necessary to react completely with 0.05 moles of nitrogen?
- (b) How many moles of ammonia are produced?

4.23.1 Objective:

This question tested whether students can carry out calculations involving mole ratios by using verbal reasoning or balanced equations.

4.23.2 Solution: (Tested only on the 2014 group).

- (a) From the equation the mole ratio H_2 : N_2 is 3:1

$$\therefore \text{moles } \text{H}_2 = 3 \times \text{moles } \text{N}_2$$

$$\therefore n\text{H}_2 = 3 \times 0.05 \text{ moles} = 0.15 \text{ mol}$$

(b) From the equation the mole ratio $N_2: NH_3$ is 1:2

$$\therefore \text{moles } NH_3 = 2 \times \text{moles } N_2$$

$$\therefore nNH_3 = 2 \times 0.05 \text{ moles} = 0.10 \text{ mol}$$

4.23.3 Results:

The results to question 22 are shown in table 4.22.

Table 4.22: Question 22 Summary of Results.

	N (frequency)			Percentage		
	2014			2014		
	Cor	Inc	Mis	Cor	Inc	Mis
(a)	36	32	28	38	33	29
(b)	13	50	33	14	52	34
Ave	25	41	30	26	42	32

4.23.4 Discussion of Results:

This question tested the same skills as question 21, and the students' performance was very poor with both group scoring below 40%. The results for the sub-questions are discussed as follows;

- i. In part (a), students' performance was poor with 38% of correct answers, 33% incorrect answers and 29% of the group did not attempt to answer the question.
- ii. In part (b) the students' performances were also very poor with 14% of correct answers, 52% of them answered incorrectly, and 34% did not attempt to answer the

4.24 General conclusions from results of pre-test

4.24.1 Language Skills

Students' performance varied. In some sub-questions they scored well above 75%, but in the majority of the sub-questions they scored below 50%, despite the fact that in this group 50% of the 2013 students and 60% of the 2014 students studied in the English medium at high school. Although this group studied in high school their main home language was generally not English, but Setswana, Sesotho, Isizulu etc. This indicates that students who take English as first language at school, but speak a different language at home, also have difficulty in understanding the language used in chemistry. This is in agreement with studies done by Oyoo (2013): that the types of difficulties encountered by students are the same irrespective of whether they learn in the first or second language.

This study found that many non-technical words used in scientific context can cause difficulties for students. For example, in question 1 about 50% of the students did not understand the meaning of the word "deduce". Deduce in scientific context, refers to making a conclusion by thinking about the known facts. Similar conclusions were also found in studies by Cassels and Johnstone (1980) and Song and Carheden (2014): that meanings of everyday words cause difficulty to students when placed in scientific contexts.

In question 2, 25% of students could not distinguish between descriptive and explanatory statements. These are meta-representational non-technical words that signify thinking (Oyoo, 2011). Students failed to recognize that descriptive statements are narrative whereas explanatory statements give reasons. Being unable to distinguish the difference between the words "describe" and "explain" will contribute to failure at examinations because students may give a descriptive answer (and get zero marks) when they are asked for an explanatory answer.

4.24.2 Verbal reasoning skills

Verbal reasoning needs students to analyse phrases, make comparisons, classify, make inductive and deductive conclusions. For example in question 8 which tested students' ability to represent verbal information as a diagram, students' performance was very poor: only about 30% answered correctly. These students were unable to represent the verbal information given as a diagram.

In some questions which tested competence in inverse and direct proportion reasoning, students were required to do comparisons and draw conclusions. The results seemed to show that students did not understand the meanings of some words and the relationship between them. They also did not convert the verbal statements into diagrams or equations to solve the problems. Question 16 tested students' abilities in analogical reasoning. It needed the processing of information by comparisons of the similarities between different concepts. About 40% of the students were unable to make associations between the words given to familiar words.

The study also showed that the students' metacognitive thinking abilities are somewhat limited. For example in question 19 which needed the use of prior knowledge to proceed with necessary steps to reflect and solve problems, they performed very poorly. They also failed to analyse the verbal statements by comparing different pieces of information and make inferences to solve problems which required simple calculations. This is in agreement with the findings of Nelson (1992). In question 11, which asked about inverse proportion reasoning, the majority failed, due to lack of following instructions and using equations to solve problems from verbal statements. In questions 12 which needed the students to use direct proportion reasoning to solve problems given in verbal statements, they failed to interpret the questions.

Some of the skills tested were repeated in different questions. This was done to check the validity and reliability of the results, which will guide the design of the post-test question paper. Some of the examples are:

- (i) Questions 1 and 7, both questions tested the understanding of the word “Emission”, and the students’ average performance were 77% (question1) and 75% (question7);
- (ii) Questions 6, and 11 both questions tested ability to identify “variables” given in verbal statements , and the students’ average performance were 41% (question6) and 45% (question11)
- (iii) Questions 15, and 17 both questions the understanding of the meanings of the word “endothermic”, and the students’ average performance were 69% (question15) and 71% (question17)

4.25 Student-student interactions (SSI)

Transcripts of voice recordings of two groups the students (students in both 2013 and 2014) were studied in March 2015. Although, at the beginning, four groups of students were present, only two groups’ recordings (11 students) could be analysed since the other two groups’ recordings were not audible.

The aim of this study was to explore how students start their own problem-solving process and also to give them the opportunity to express their ideas without the interference of the instructor.

The students worked through the pre-test question paper. They chose those parts within each question that caused difficulties. They talked in Setswana often while talking to each other, showing that they thought in Setswana even when discussing English words. In the tables below the columns are as follows:

- Column 1 indicates the actual words used by students with mixed language;
- Column 2 indicates the “translated” correct phrase for the first column with mixed language, where necessary;
- Column 3 indicates the final answer written down by the group.

4.25.1 Group 1 (2013 students)

This group had five members and the total recording time of 1h:17m:45s.

Question 2

Which of the following statements are descriptions and which are explanations? Briefly give reasons for your answers.

2(e) The rate of diffusion of hydrogen gas is higher than that of oxygen gas because hydrogen molecules, being smaller, move at a faster speed.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: It is a description.		2(a) It is an explanation.	Only 2 students were talking to each other. Although student 1 said it is a description, she did not give the reason why she said that to the other student. Student 2 gave the correct answer. Students 3, 4 and 5 were inactive.
Student 2: <i>Nna kare ke</i> explanation- <i>ka gore e tlhalosa</i> why rate of hydrogen <i>e le ntsi</i> , due to hydrogen molecules being smaller	Student 2: I am saying it is an explanation because it clarifies why rate of hydrogen is higher, due to hydrogen molecules being smaller.		

2(f) In a neutral atom, the number of electrons is equal to the number of protons.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: It is very simple, it's description.		2(f) It is an explanation.	The students failed to answer the question correctly. Surprisingly student 2, who managed to answer 2(e) correctly, indicated that she was confused and unable to differentiate between descriptive and explanatory statements. Student 1 who indicated that the question was simple failed to give others clarity why she said so. Student 4 indicated it is a fact, this showed that she did not know what the question was asking. Student 5 was inactive. The group moved on to the next question.
Student 2: Even though you said it's simple, I am still not able to differentiate between descriptive and explanatory statements.			
Student 3: I think it's an explanation because it explains <i>gore mo</i> neutral atom basically <i>go na le eng</i> ?	Student 3: I think it's an explanation because it explains what is basically inside the neutral atom?		
Student 4: This a fact, a statement which cannot be changed			
Student 2: I am undecided not agreeing with all what you are all saying.			

Question 3

Which of the following statements are qualitative and which are quantitative? Briefly give reasons for your answers.

3(a) The density of a substance is the mass per unit volume.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: This quantitative statement.		3(a) Quantitative.	Student 2 indicated to her group members that quantitative statements can be written in the form of an equation but could not give an example for this. In addition student 5 tried to give an example, with “100% pass rate” using numbers. Students 1 and 3 remain confused especially in the part where student 2 indicated that quantitative statement can be converted into equations.
Student 1: What do you mean? I don't understand.			
Student 2: Qualitative it means quality and quantitative means quantity.			
Student 5: Trying to clarify; let's say <i>ke batho ba ba</i> ten, <i>ba kwala</i> test <i>botlhe</i> , then <i>ba pase botlhe</i> it is quantitative.	Student 5: Trying to clarify; let's say for example we have ten students writing a test and the results indicate 100% pass rate then it is quantitative.		
Student 2: Quantitative can be used in a form of equation.			
Student 1and 3: This is confusing where does the equation fit in the quantitative statements?			

3(b) A litre of water is heavier than a litre of ethanol.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1 and 3: It's quantitative. Student 2: Because they are talking about weight "heavier". Student 5: No it is qualitative.			The group did not write their final answer, although some tried to clarify the question. It showed that they did not understand the difference between the words quantitative and qualitative.
Student 2: No <i>re bua ka</i> weight <i>reya itse gore ke</i> mass. Student 5: This is qualitative.	Student 2: No here we are talking about weight which refers to the mass.		

3(c) The rate of diffusion of a gas is inversely proportional to the square root of its molar mass.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1,2,3 and 5: It's obvious this is quantitative.		3(c) Quantitative.	Four students agreed that this is a quantitative statement, without giving reasons. The reason might be that they were familiar with the phrase. Student 4 was inactive.

3(d) Ice melts at 0°C.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: This is qualitative.		3(d) It is a qualitative statement.	Students were confused about the words “melt” and “freeze. The failed to realize that there was a measurable quantity (0°C), and that the statement is quantitative, even though a number was given. Students 3 and 4 were inactive.
Student 2and5: <i>Akere metsi a melter</i> ka 0°C, <i>ba bua ka</i> quality of water.	Student 2and5: Isn't it that water melt at 0°C, it means they refer to the quality of water.		
Student 2: But at 0°C <i>metsi a</i> icer, but <i>hei...</i> not sure!	Student 2: But at 0°C water freezes, but I'm not sure about this!		
Student 1, 2and 5: We conclude that it's a qualitative statement.			

3(e) The rate of reaction increases in the presence of a catalyst.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Qualitative <i>ka gore</i> rate of reaction depend on the quality of catalyst.	Student 2: Qualitative because rate of reaction depend on the quality of catalyst.	3(e) Qualitative.	Only student 2 responded, although she said it is a qualitative statement the reason to support her answer was wrong.

3(f) Silver is a better electrical conductor than copper.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: <i>Ke</i> qualitative <i>le yona</i> because they explain the difference between properties of silver and copper. Meaning silver has more quality than copper.	Student 2: It is also qualitative because they explain the difference between properties of silver and copper. Meaning silver has more quality than copper.	3(f) qualitative statement.	Again student 2 answered correctly, but the reason to support her answer was incorrect. She said the statement explains, it does not but described that silver is a better electrical conductor than copper. Other group members were inactive.

Question 4

Consider each statement given below and state whether it is best considered to be an experimental fact, law, an opinion, a definition, or a theoretical statement. Make comments to justify your answers.

4(a) The temperature at which water boils is 100°C.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: It is a fact.		4(a) It is a Fact.	Student 5 answered correctly, and supported by student 1 who tried to provide the reason for their choice. Student 3 and 4
Student 2: Why <i>o re ke</i> fact?	Student 2: Why are you saying it is a fact?		

Student 1: Because it cannot be changed and it has always been like that.			were inactive.
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4(b) Water dissociates to form H^+ and OH^- ions.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Fact, because we know that for water to be formed, it must be the combination of H^+ and OH^- .		4 (b) It is a fact.	The group's final answer was that the statement is a fact. But throughout their conversation student 3 and 5 had a hint that this is a theoretical statement. They ended being confused and not sure after student 2 refused to agree with them. Students 1 and 4 were inactive.
Student 3 and 5: We can say it's a fact or theoretical statement.			
Student 2: You mean theoretical statement! Theoretical, why? No guys' theory <i>tota!</i>	Student 2: You mean theoretical statement! Theoretical, why? No guys' do you really mean it's a theory!		

4(c) Effusion is the escape of a gas through a small hole.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: <i>Tota ke tla bo kelo aketsa ga ke itse gore effusion ke eng? Akere jaanong diffuse ke go kopana?</i>	Student 2: Honestly I will be lying, I don't know what effusion is? Isn't that the word diffuse means maybe to combine?	4(c) It is a Definition.	Only two students (1 and 2) participated, with student 1 clarifying to student 2 because she indicated that she doesn't know what effusion is. Students 3, 4 and

Student 1: This is definition, because it defines what effusion is.			5 were inactive.
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4 (d) The total mass of a system remains constant during a chemical reaction.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: Ke definition.	Student 5: It is definition.	4(d) it is a law.	Student 5 said it was a description but did not clarify until student 2 asked them to go through the question again. Student 3 gave the right answer that it is a law but failed to provide the reason as asked by student 2 why it is a law? Students 1 and 4 were inactive.
Student 2: In a shock! Definition <i>tota! A re baleng potso gape?</i>	Student 2: <i>In a shock!</i> Definition Really! Let us read the question again.		
Student 3: It is a law.			
Student 2: Which law?			

4(e) Density is mass per unit volume.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: It's a law		4(e) Definition	Three students participated giving different answers without giving any clarity for their choice of answers. Students 4 and 5 were inactive.
Student 1 and 2: It is definition			

Question 5

There is a wrong word in each of the following statement. Circle the wrong word and write the word which will make the sentence correct.

Question 5 (a) has been answered to give a clue on what is expected.

5(a) When a water sample is heated, temperature is absorbed and therefore the temperature will increase.

Answer: Heat

5(b) The percentage of girls in a class of boys and girls is 200.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: 200 is the wrong word.		5(b) Wrong word "percentage" and right word "number".	Students 1, 3 and 5 were correct, with the right reason given by student 5. Although they all agreed to write wrong word as percentage, student 5 stick to her point of the wrong word being 200, and right word being 100. The group wrote student 3's answer that the wrong word is percentage and the right word is number. Student 4 was inactive.
Student 3: The wrong word is percentage; the right should be number of...			
Student 5: <i>Wena ekare o</i> changer the whole sentence, <i>akere ba re</i> wrong word.	Student 5: It seems you want to change the whole sentence, the question is asking for the "wrong word".		
Student 2: "No <i>re</i> circler the wrong word thereafter write the right word.	Student 2: We have to circle the wrong word thereafter write the right word.		
Student 5: Percentage can't be 200, <i>di felela ka</i> 100.	Student 5: Percentage can't be 200, they end		

	up to 100.		
Student 2: The “total number” is the right word.			
Student 3: No, the question said circle the wrong “word” not “words”, now “ <i>wena</i> ” you change the whole sentence.	Student 3: No, the question said circle the wrong “word” not “words”, now you want to change the whole sentence.		
Student 5: Just one wrong word, I stick with my point that percentage <i>e ka se nne</i> 200 but 100	Student 5: Just one wrong word, I stick with my point that percentage can’t be 200 but 100.		

5(c) The temperature of a water sample can be calculated using a thermometer.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students’ deliberations:
Student 4: Calculated <i>ke</i> wrong word and measured <i>ke</i> the correct word.	Student 4: Calculated is the wrong word and measured it is the correct word.	5(c) wrong word calculated and right word measured.	Student 4 managed to pick the wrong word fast, with student 2 confessing that indeed she would perform better in chemistry if she understood the words.
Student 2: <i>Mos daan fa nkabo ke itse</i> meaning of some of the words <i>nkabo ke tshwara</i> distinctions <i>mo</i> chemistry.	Student 2: This really shows that if I knew the meaning of some of the words I would be scoring distinctions in chemistry.		

5(d) Since 100 grams of atmospheric air contains 21 grams of oxygen, we can deduce that the percentage of oxygen in air is 21 grams.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 4: Hee, percentage can't be grams.	Student 4: No, percentage can't be grams.	5(d) wrong word is percentage and right word is amount.	Student 4 was correct that the percentage cannot be in grams, but failed to give the correct unit for percentage. Whereas student 3 gave the wrong reason and they ended up giving the wrong answer. Students 1,2 and 5 were inactive.
Student 3: Meaning the wrong word is percentage and has to be replaced by the word amount.			

5(e) The volume of a gas is 100 grams.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 4: The word "grams" is wrong.		5(e) wrong word volume/grams and right word mass/ cm^{-3} .	Student 4 indicated that word "grams" is wrong, but did not give the right units for volume. Then student 2 suggested two options that they can change the word volume and replace it with mass. Alternatively they can leave the volume as it is and only change grams to cm^3 .
Student 3 and 5: It can be cm^3 or dm^3			
Student 2: <i>Re kgona go</i> changer volume to mass or grams to dm^3 / Liters.	Student 2: We can change the volume to mass or grams to dm^3 / Liters.		
Student 1,3,4 and 5: Agreed that student 2 is correct, they can use both options.			

Question 6

Convert the following statements into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statements (a)

The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a).

Answer: Variable quantities are R (resistance), l (length) and area (a), Equation: $R = k \frac{l}{a}$

6(b) The concentration of a solute A in a solution is defined as the amount of A present per unit volume of the solution.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Answer is $C = \frac{n}{v}$		6(b) $C = \frac{n}{v}$	2 Students in the group answered the second part of the question. They failed to identify variable quantities, although they were given a clue in 6(a). Students 1, 4 and 5 were inactive. They answered the second part of the question without first explicitly identifying the variables. However, because they could write a correct equation they were familiar with the variables and the relationship between them.
Student 3: This we use it on practicals.			

6(c) The difference between the masses of two objects A and B is 4 grams, A having the larger mass.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2 and 5: Answer is $4 = A - B$		6(c) $A - B = 4$	Students tried to answer the questions, but made a mistake of not identifying variable quantities and also failed to realize that the unit (grams) was in the question. They failed to include the units in their equation. Students 1, 3 and 4 were inactive.

6(d) The sum of the masses of two objects A and B is 13 grams.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3 and 5: Answer is $A + B = 13$		6(d) $A + B = 13$	Students did not answer the first part of identifying variable quantities. They also failed to include the units in their equation. Student 2 was amazed how the questions were so simple but their hastiness to answer questions affects their performances. Students 1 and 4 were inactive.
Student 2: <i>Ijoo a dilo tse ke tsona di re feidisitseng di le simple so, go raya gore re jagela go araba re sa tlhaloganye.</i>	Student 2: I can't believe that such simple things made us fail; this means we just rush to answer without first trying to understand the question.		

6(e) The mass fraction of A in a mixture of two substances A and B is 0.30.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: Obvious it is $0.30 = \frac{A}{B}$		6(e) $0.30 = \frac{A}{AB}$ only 2 students, then other 2 students $0.30 = \frac{A}{A+B}$	There was a serious division in agreeing to the right answer between the students, because of the word "mixture". Also students did not identify various quantities. They only focused on writing the equation. Student 4 was inactive.
Student 3: No wait, let us read the question again.			
Student 5: $\frac{A}{A+B}=0.3$, but this is a mixture, I'm not sure.			
Student 2: No we don't add it is $\frac{A}{AB} = 0.3$			
Student 1: La reng?	Student 1: What are you saying?		
Student 5: Nna ka re its $\frac{A}{A+B} = 0.3$ but student 2 is saying it is $\frac{A}{AB} = 0.3$, because of the word mixture.	Student 5: I am saying the answer is $\frac{A}{A+B} = 0.3$ but student 2 is saying it is $\frac{A}{AB} = 0.3$, because of the word mixture.		
Student 3: The correct answer is $\frac{A}{AB} = 0.3$			

6(f) The mass percentage of an element A in a compound is 30%.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: So <i>a go raya gore</i> A = 30%?	Student 3: Does this mean A = 30%?	6(f) A = 30%	Students attempted to answer the question but gave wrong responses. Also their final answer was incorrect. Students 1 and 4 were inactive
Student 2: What about the word mass and 100 for percentage?			
Student 5: <i>Akere gatwe re kwala</i> formula or equation?	Student 5: Is it that they are asking us to write the formula or equation?		
Student 3: It is $\frac{A}{30} \times 100$			
Student 2: A = 30%, because it is a mass percentage.			

6(g) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Answer is $\frac{A \times 100}{A+B+C}$		6(g) $M_A = \frac{M_A}{M_A + M_B + M_C} \times 100$	Student's responses in this question were similar to that in

Student 2: Nna ke nagana ke $A = 100 \times \frac{A}{ABC}$	Student 2: I think the answer is $A = 100 \times \frac{A}{ABC}$		6(d). Instead of adding masses of all substances, some multiplied the masses. But their final answer was correct. They failed to identify variable quantities. Students 1, 4 and 5 were inactive.
Student 3: $A = \frac{A}{A+B+C} \times 100$			

Question 7

For each of the words/phrases given below, state its meaning in column 2 and the “opposite” word in column 3.

7(a) Constant quantity.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Constant quantity meaning “quantity that doesn’t change”.		7(a) Meaning-quantity that doesn’t change. Opposite word- changing quantity.	Although the students tried to answer they failed to get the opposite word as “variable” but instead they wrote “changing”. This showed they understood the meaning of the word. Students 1 and 4 were inactive.
Student 3: It has been experimented.			
Student 2: Mam (referring to the facilitator) <i>ke ntse ke shebile di</i> question <i>tse re ntseng re di dira, di swaak bathung</i> , why <i>lo sa re fe di</i> test in groups of 2/3 <i>re discusse gore re bulege tlhaloganyo</i> .	Student 2: Mam (referring to the facilitator). I’ve been looking at all of these questions; they seem to be very easy, why we can’t be given tests in groups of 2/3 such that we discuss amongst each other, so that our minds can be clearer on		

	what we are doing.		
Student 2: If it is not a constant <i>ke eng</i> ?	Student 2: If it is not a constant what is the opposite?		
Student 3and5: Then opposite word <i>ke</i> “changing quantity”.	Student 3and5: Then opposite word is “changing quantity”.		

7(b) Absorption of heat.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Attraction of heat is the opposite word.		7(b) Meaning-heat has been taken in. Opposite word-Release of heat.	Student 5 gave the opposite word as “attraction of heat” this clarifies that meanings of some of the words are still a problem amongst students. Student 2 and 5 gave correct answers. Students 1 and 4 were inactive.
Student 5: Meaning is “heat is taken in”			
Student 2: I think opposite word is release of heat.			

7(c) Proton donor

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Substance that donate protons.		7(c) Meaning-object that donate protons Opposite- Proton acceptor.	Only student 2 and 3 tried to answer the question, but just rearranged the phrase and did not explain the words. Students 1, 4 and 5 were inactive.
Student 3: Opposite word is proton acceptor.			

7(d) Negative Charge.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Charge that gains electrons.		7(d) Meaning-The charge that is obtained when electron/s are gained Opposite- Positive Charge.	Although student 2 knew the meaning of the word, student 5 disagreed with her. But they did not encounter problems in giving the opposite phrase.
Student 5: Hee!	Student 5: No!		
Student 2: It shows it has gained electrons.			
Student 5: Opposite word is "positive charge".			
Student 2: Then what will be the answer because le gana gore it gained electrons.	Student 2: Then what will be the answer because you are disagreeing that it gained electrons?		
Student 3: Charges obtained when electrons are gained.			

7(e) Theoretical Statement

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: It is a statement that has been experimented.		7(e) Meaning-statement that has been proven scientifically Opposite word- Actual Statement.	In this question students who attempted to answer were confused. Really they didn't know the meaning of the word. Students 1, 4 and 5 were inactive.
Student 3: This is a scientifically proven statement.			

Student 2: I am confused some are saying it is opinion or actual statement?			
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7(f) Product of reaction.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Obtained after reaction, ke something obtained after reactants react together. A yield after reaction takes place.	Student 2: Obtained after reaction, it is something obtained after reactants react together. A yield after reaction takes.	7(f) meaning- Reactants reacts to form products. Opposite word- Reactants of Reaction.	Student 2 actually was on the right track, except that the other student was giving the meaning of the opposite word. Student 2 tried several times to show that students 3 and 4 are talking about reversible reactions. Also they were not saying the same thing. They ended up being confused. Student 1 was inactive. Students spent more than 10 minutes deliberating on this question.
Student 3: Reactants are produced from products.			
Student 2: No reactants produce products, not the other way round.			
Student 4: I agree with student 3.			
Student 2: Nna kea gana your statement is wrong?	Student 2: I totally disagree your statement is wrong?		
Student 3: I am saying it's a reaction whereby reactants are formed from products. Re bua the same thing referring to student 2.	Student 3: I am saying it's a reaction whereby reactants are formed from products. We mean the same thing referring to student 2.		
Student 2: No ways we are not referring to the			

same thing.			
Student 5: No referring to student 3! You are now talking about the reverse reaction. <i>Tlhogo tsa rona ga di bereke.</i>	Student 5: No referring to student 3! You are now talking about the reverse reaction. Really we are not thinking straight.		
Student 2: <i>Nna ka re</i> reactants form products, and I stick to my point.	Student 2: I am saying reactants form products, and I stick to my point.		
Student 3: <i>Kante nna ka reng?</i>	Student 3: So what do I mean?		
Student 2: <i>Wa re</i> products form reactants.	Student 2: You said products form reactants.		
Student 2: The opposite word is “reactants of reaction”.			

7(g) Exothermic reaction.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 4: Heat has been released.		7(g) Meaning- the release of heat (2 Students).	They mentioned two meanings saying “heat is released” and the other as” heat has been absorbed”.
Student 2: Heat has been absorbed.		Meaning- number of products is more than number of reactants.	The other student suggested a graph which shows endothermic and exothermic. It was easier to give the opposite word. Students 1 and 5 were inactive.
Student 4: Let's do graph showing endothermic and exothermic.		Opposite word- endothermic.	
Student 3: Heat has been released.			

Student 4: Opposite word is endothermic.			
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7(h) Reversible Reaction.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Reactants formed from product (referring to student 3) it was what you were saying for the phrase "product of reaction".		7(h) Meaning-Reactants can form products, and also products can form reactants Opposite word-Forward Reaction.	Again in this question student 2 tried to clarify to students 3 and 4 that they answered this question in 7(f). She also showed them that a reversible reaction can be spotted by double arrows. Opposite word was not correct. Students 1 and 5 were inactive.
Student 2: Forward and Backward it means you can form reactants from products, represented by arrows with the other facing left and the other facing right.			
Student 4: Yes I agree.			

7(i) Oxidation.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Reduction is opposite word.		7(i) meaning- loss of electrons Opposite word- Reduction of reaction.	Student 2 again explained to other students. She further tried to clarify to student 4 that reduction in chemistry doesn't refer to its everyday meaning. She had
Student 2: Oxidation is the loss of electrons.			
Student 4:			

Oxidation it is not dealing with ions, but reduction deals with losing electrons.			learned the definition of oxidation. Students 1 and 5 were inactive.
Student 2: <i>Hmmmm</i> No! It doesn't mean that "reduction" <i>gore ke go fokotsega mo</i> , like it was used in everyday meaning, <i>ga go reye gore di</i> electrons <i>di a fokotsega</i> , it means gaining of electrons. But oxidation is the loss of electrons.	Student 2: No! It doesn't mean that "reduction" refer do the decrease like it is used in everyday meaning. This doesn't mean that the electrons are becoming less, it means gaining of electrons. But oxidation is the loss of electrons.		

Question 8

Two cars, 160 km apart on a main road, travel towards each other. The first car travels for 20km and takes a right turn and travels for 15 km. It then turns left and travels for another 30km, and then turns left again and returns to the main road. In the meantime, the other car travels 40 km along the main road.

- i. Represent all the information given above as a diagram
- ii. What would be the distance between the two cars?

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Clarifying to the group; <i>ke kolo tse pedi, go raya gore ga di tsamaye tsela ele</i> one, "towards" <i>go raya go di tla di</i>	Student 2: Clarifying to the group; These are two cars travelling towards each other on the opposite lanes.	distance between these cars is $160-60 = 100$ km.	Although student 2 tried to describe how the cars move, their answer for calculating the distance was incorrect. They did not realize

lebagane.			that after a right turn and a left turn, the first car would again be traveling towards the second car. Students 1, 2 and 4 were inactive.
Student 5: Draw the diagram.			
Student 5: Calculated, distance travelled is $20+40= 60$, therefore the distance between these cars is $160-60 = 100$ km.			

Question 9

This question concerns the masses of 5 objects A, B, C, D and E. The mass of A is larger than the mass of B by 4g but is smaller than mass of C by 2g. The mass of D is smaller than the mass of A by 2g but is larger than mass of B. Object E has the largest mass of 10g.

(a) Which object will have the smallest mass?

(b) Arrange all the objects in order of increasing mass (i.e., start with the object that has the lowest mass).

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Answer is B, after arranging all objects.		9(a) B 9(b) B, A, C, D, E	Only student 2 gave the answers.

Question 11

Three men need ten hours to tile the floor of a house

(a) Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer)

- (i) Men and floor of the house; (ii) Three men and ten hours;
- (iii) Number of tiles and surface area of the floor; (iv) Number of men and time.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 4: What do we mean by physical quantities?		11(a) (i)	Although the students tried to answer they failed to pick up the right option (iv). They struggled to identify variable quantities. They gave the wrong definition of “physical quantities” confusing it with “physical” in everyday life. They therefore looked for things they could see and touch, and did not choose time.
Student 2: Something that you can feel and touch.			
Student 3: Number (i) is correct.			

11(b) Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct)

- (i) Directly proportional; (ii) Exponential;
- (iii) Quantitative; (iv) Inversely proportional;
- (v) Qualitative.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
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Student 5: Directly proportional and inversely proportional.		11(b) (i) and (iv)	The students were confused about the words directly and inversely proportional, and wrote option (i) and (iv). Student 5 had learned the definitions by rote, but could not apply them consistently.
Student 3: You can't state two relationships.			
Student 5: No, the statement said more than one answer can be correct.			
Student 2: Asking student 5, for example equation $c = \frac{n}{v}$, which one is inversely proportional and which one is directly proportional, because I'm confused.			
Student 5: Directly proportional is when one quantity increases the other also increases with the same proportion. Inversely proportional is when one quantity is increasing the other decreases with the same proportion.			
Student 2: <i>Gao nthute, ke nna</i> worse, <i>ga ke utlwe?</i>	Student 2: Actually I can't make sense of anything you said, you make things worse for me.		

Student 5: Giving example using question 6(a) The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a). $R = k \frac{l}{a}$, this means when (R) increases, (l) will also increase.			
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11 (c) How many hours will be needed by four men, working at the same rate, to tile the floor of this house?

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Answer is $\frac{10}{4}$		11(c) It is $\frac{10}{4}$	Only student 2 gave the answer, and the other group members were inactive. She used an inversely proportional relationship, but did not apply the equation correctly.

In Questions 1,12-24:

The students mentioned that they understood the questions, and did not work through them.

4.25.1.1 Group one general findings:

Group had 5 members. Students chose to start with question two, as the instruction said they must discuss questions which gave them difficulty. They did sub-questions 2(e) and 2(f). In sub-question 2(e) only two students engaged with each other, although student 2 gave the correct answer that the statement was explanatory. But in sub-question 2(f) all students participated but failed to come up with the correct answer and wrote that the statement is explanatory, whereas the statement was a descriptive statement.

In question 3, students answered sub-questions 3(a)-3(f), those sub-questions which were answered correctly were (a), (c), (e) and (f), but for sub-questions (b) and (d) they gave wrong answers. In sub-question (b) the statement was “a liter of water is heavier than a liter of ethanol”, students confused the word “heavy” and mentioned that it refers to “mass” or “weight”, and end up giving wrong response that it is quantitative. In sub-question (d) the statements was “Ice melts at 0°C”, student mentioned that it refers to the quality of water, and confused the word “melt” used in the phrase with the words “ice” and “freeze”.

In question 4, students answered sub-question 4(a)-4(e), with correct answers for sub-question (a), (c), (d) and (e). Statement (d) caused confusion amongst students even though two students were correct that it is a theoretical statement but others disagreed with them, resulting in them answering incorrectly.

In question 5, students answered sub-questions 5(b)-5(e). The correct answers were given for sub-question (b), (c), (e). Sub-question (d) was answered incorrectly, and only two students were active, with the first giving the hint that percentage cannot be in grams, and the other mentioned that the word “percentage” in the phrase is wrongly placed and should be replaced with the word “amount”. This student switched to the everyday use of the word “amount” which refers to “how much of a substance is there”, whereas the use of the word in the

chemistry context had different meaning which refers to “the measure of the number of particles (i.e. atoms, molecules, ions, electrons and etc.) present. This resulted in them giving the incorrect answer.

In question 6, students answered questions 6(b)-6(g), the sub-questions which were answered correctly were (b), (c), (d) and (g). Although the students answered correctly, like in the pre-test they failed to identify “variable quantities” but only giving the equations without assigning symbols to them except for part (d) in which they had assigned symbols in the written equation. In sub-question (e) students wrote two different answers, although the other group’s answer was correct, they had disagreements, and confused the word mixture, and instead of adding two substances which make a mixture they multiplied them. In sub-question (f) student failed to realize that the percentage is calculated as a fraction multiplied by hundred, and they ignored the word compound in a phrase, and wrote equation as $A = 30\%$.

In question 7, the students answered sub-questions (a)-(i), they were required to give the meaning and opposite phrase of the words. For giving the meaning of the word the correct sub-questions were (a), (b), (c), (d), (f), (g), (h) and (i). Only sub-question (e) students gave the incorrect meaning, indicated that the meaning as “the statement that has been proven scientifically”, in which the meaning they gave refer to the “fact”. For giving the opposite word the correct sub-questions were (a) although they used the everyday meaning of the word unlike using the chemistry meaning which is a “variable”, (b), (c), (d), (f), (g) and (i). In sub-question (e) the word “theoretical statement” gave them difficulty as they indicated that the opposite word is “actual statement”, and also part (d) they indicated the opposite word as “forward reaction”, which was incorrect.

In question 8 both answers were incorrect, firstly they failed as a group to represent all information in a form of a diagram, and secondly they didn't do the right calculation but only added the values travelled by both cars leaving the 30 km of car A.

In question 9, students managed to identify the object with the lowest mass, but failed to represent the information in a diagram.

In question 11, in part (a) students failed to identify variable quantities, giving the incorrect answer as "men and floor of the house" instead of "number of men and time". In part (b) which required the relationship between the variable quantities, two parts were correct which were option "ii" and "iv", they answered one part correctly which is "iv", and gave the incorrect one as "i". In part (c) students were asked if four men will take more or less hours to tile the floor of the house, and also to indicate how they arrived to the answer. The group answered incorrectly, caused by the difficulty in writing the correct relationship between men and time; instead they divided the number of hours by four men. This showed that they lacked inverse proportion reasoning skills.

4.25.2 Group 2 (2014 students)

This group had 6 members and the total recordings time of 1h: 07m: 15s.

Question 2:

Which of the following statements are descriptions and which are explanations?

2(a) The pressure of a gas is due to the continual bombardment of the walls of the containing vessel by the molecules.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: <i>Ke nagana gore ke</i> explanation, <i>ka gore</i> it clarifies that it's a process, and answer the question like why? And it gives reasons.	Student 1: I think it is explanation, because it clarifies that this is a process, and answer the question like why? And it gives reasons.	2(a) Explanation-it explains what causes pressure of a gas.	Although in their final write up, students indicated that this is an explanatory statement, they did not mention that it gave reasons in terms of particles present. Students 1 and 6 were inactive.
Student 2: <i>Nna kare ke</i> description.	Student 2: I think it is description.		
Students 3: No it is not description but explanation, because it explains the cause of pressure, it gives details on causes of pressure.			
Student 4: No, why <i>lore ke</i> explanation?	Student 4: No, why are you saying it is explanation?		
Students 5:	Students 5:		

ka gore it doesn't tell what is pressure but gives the reason gore pressure e dirwa ke eng? What is the cause of pressure?	Because it doesn't tell what pressure is? But it gives the reason what causes the pressure?		
Student 4: Ok it sheds light on what causes the pressure. Oh now I understand it gives reasons.			

2(b) The percentage of oxygen in the air is 21%.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: <i>Ke</i> description.	Student 3: It is description.	2(b) Description-gives description, does not answer the question why?	Students spent more than 12 minutes on this question, arguing and becoming confused about the final answer. It showed they were really struggling to figure out that this was a descriptive statement. The confusion arises in failing to focus on the definitions of descriptive and explanatory statements. Student 1 was inactive.
Student 5: Why <i>o re ke</i> description?	Student 5: Why are you saying it is description?		
Student 3: Because it doesn't answer the question why? It just tells you.			
Student 5: It gives details of oxygen.			
Student 3: Yes it just gives details.			
Student 2: But I can see 2b is quite confusing. <i>Bona akere</i> the percentage of oxygen in the air is 21%, is it explaining why percentage is 21% or is it describing?	Student 2: Look isn't this telling us that the percentage of oxygen in the air is 21%. Is it explaining why percentage is 21% or is it		

	describing?		
Student 3: It just describes.			
Student 2: <i>Kante gona le</i> difference between to describe and to explain?	Student 2: Tell me is there a difference between to describe and to explain?		
Student 3: Yes there is a difference.			
Student 2: Oh ok, if <i>o</i> describer <i>o ya</i> in details, like <i>o re mang mang o apere coat ya</i> colour <i>e</i> red?	Student 2: Look when you describe you go further giving details, for example when you say someone is wearing a red coloured coat.		
Student 3: <i>Ya ka gore</i> it answers the question why?	Student 3: Yes because it answers the question why?		
Student 4: “Describe”, No guys, it tells what something is? And gives details of characteristics without reasons.			
Student 3: Yes 2b is descriptive, because it gives details.			
Student 2: <i>Ijooo!</i> Is it description?			
Student 3: Yes it is.			
Student 2: <i>Oook!</i> (but not sounding satisfied)			
Student 2: No guys we cannot conclude <i>pele nna</i>	Student 2: No guys we cannot conclude		

gake sure gore ke wela kae?	before I can be sure on how I can figure this out?		
Student 4: We are still confused, kana jang bathung?	Student 4: We are still confused isn't that so guys?		
Student 2: A re kwaleng our different answers that we are disagreeing.	Student 2: It will be best to write our different answers that shows we are disagreeing.		
Student 4: Kante why re sa bue and state our confusion?	Student 4: Why can't we state the cause of our confusion?		
Student 2: Wena why o re ke explanation? "Referring to student 5" kante is there a difference between to describe and to explain?	Student 2: Tell us why are you saying it is an explanation? "Referring to student 5" Is there a difference between to describe and to explain?		
Student 3: Ke description because it has only one detail, it does not answer the question why or shed any light?	Student 3: It is description because it has only one detail; it does not answer the question why or shed any light?		
Student 5: But what if there is a question asking what percentage of oxygen is in the air?			
Student 3 and 4 : It is 21%.			
Student 2: But if o re ke description ga e describe sepe e bua fela gore ke eng?	Student 2: But if you say it is description it does not describe anything, it just tells us what it is?		

Student 4: It first gives reason, and answer the question why?			
Student 5: Please note description mostly <i>ke</i> how?	Student 5: Please note description mostly answers the question how?		
Student 2: So what do you think and the way forward?			
Student 5: I'm not disagreeing nor agreeing" I'm there but confused.			

2(d) The rate of diffusion of hydrogen gas is higher than that of oxygen gas because hydrogen molecules, being smaller, move at a faster speed.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 1: It is explanation because it explains about the rate of diffusion. But the sentence has the word "because".		2(d) Explanation- It sheds light on the diffusion of hydrogen and oxygen. It explains why the rate of diffusion of hydrogen is higher than that of oxygen.	Their final answer was an explanation, but listening throughout their conversation, it seems some of the group members were left behind and unable to reach a conclusion. Student 3 showed he had a clue on how to "target" words in an explanatory statement, but the words he used were not always referring to an explanatory statement. He also advised the fellow group mates to play their roles in learning. But student 4 felt
Student 3: Words like "due", "because" and "between" actually explains the differences.			
Student 4: It explains why the rate of diffusion of hydrogen is higher than that of oxygen			
Student 3: <i>Hmmmmmm ao bua nnete?</i> it is a	Student 3: Are you sure? It is a descriptive		

descriptive statement.	statement.		that they needed more clarification from their lecturer regarding this. All students participated.
Student 4: You know our lecturer tried to clarify this in class but I wish she could have stated many other examples.			
Student 3: Guys we also need to play our roles in learning.			

Question 3:

Which of the following statements are qualitative and which are quantitative?

3(b) A litre of water is heavier than a litre of ethanol.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: Before we can answer this question what is the difference between quantitative and qualitative statements?		There is no problem, we understand the difference between qualitative and quantitative statements.	The groups summarized their final answer for the entire question 3, indicating that they understood the difference between the words, but their conversation concerning question 2(d) showed that they did not understand. They agreed due to pressure from their group members but were unable to differentiate between quantitative and qualitative statements. Although student 6 had correctly defined the terms. They were unable to apply the definitions. The word "litre" was a
Student 6: Quantitative can be changed into equation but qualitative cannot.			
Student 2: A liter of water is quantitative.			
Student 5: If it can be measured or have a number only?			
Student 4: Oh it is something existing in a range of			

magnitude, so this statement is quantitative.			problem, because some said it can be measured since it is a definite volume. Student failed to interpret the question properly, although student 5 had the right idea. Students 1 and 3 were inactive.
Student 5: No, it is not, for example her material is stronger than mine, it talks about quality not quantity.			

Question 4

Consider the statement given below and state whether it is best considered to be an experimental fact, law, an opinion, a definition or a theoretical statement.

4(a) The temperature at which water boils is 100°C.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: No guys question four is straightforward.		4(a) Fact-water has been proven to boil at 100°C.	This was very clear to students as they indicated that it can be verified experimentally, although students 1 and 6 were inactive.
Student 4: What do you mean by straightforward			
Student 5: Because you have to know the definitions of these words, let's take one example.			
Student 5: 4(a) is a fact because it has been proven and can also be tested and verified.			

Student 2, 3, 4: Yes it is true.			
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4(b) Water dissociates to form H^+ and OH^- ions

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Not always, not all the time that it dissociates this way; it depends on the type of reaction whether is acid-base or redox reactions.		4(b) 2 Students said it is an opinion because there are different types of reactions which includes redox and acid-base reactions. 1 Student said it is a theoretical statement, because when water reacts with something the H^+ ion detaches. 1 Student said it is a fact, because it has been proven that when water dissociates H^+ always detaches from the OH^- .	In this question students gave mixed responses towards reaching the final answer, and ended up writing their different answers. Again student 5 had an idea but could not clarify it. They did not focus on the definitions of the words; fact, law, an opinion, a definition or a theoretical statement. In this question students took more than 8 minutes to reach their conclusion. Student 1 was inactive.
Student 5: This is a theoretical statement- it's a theory.			
Student 2: Why are you saying it's a theoretical statement?			
Student 5: <i>Akere e ke theory, heish kereng ke beye jang?</i>	Student 5: This is theory, but I don't know how to clarify this to you?		
Student 4: <i>Waitse</i> what I know about a theory <i>ke gore e</i> explainer, <i>or ke reng?</i> <i>Sheba di</i> theory <i>tsa ga</i> "Newton" it is the best examples because it explains observations and predicts new ones.	Student 4: What I know about a theory is that it explains. I really don't know how to put this? But let's say for example; Newton's theories are the best examples because they explain observations and predict new ones.		

Student 5: Exactly! Thank you my friend you just answered me.			
Student 4: It is a conceptual statement, which explains observations. Guys not theories are always mental; they cannot be proven by experiments, <i>go tshwana le</i> gravity.	Student 4: It is a conceptual statement, which explains observations. Guys not all the theories are always mental; they cannot be proven by experiments, for example like gravity.		
Student 2: <i>No, ga lo</i> observe dissociation.	Student 2: I disagree; there is no way that you can observe dissociation.		
Student 3: This is an opinion because there are different types of reactions, like redox.			
Student 6: Is this redox reaction?			
Student 5: Do you mean when water reacts with something it remains to be water?			
Student 3: No it can form alcohol.			
Student 4: But the way I see it is a fact.			
Student 6: No it is theoretical.			
Student 4: No <i>maan ijoo</i> ! This question it's like a fact because it has been proven that when water dissociate it forms H^+ and OH^- ions.	Student 4: No ways! This question it's like a fact because it has been proven that when water dissociate it forms H^+ and OH^- ions.		

Student 2: <i>So potso e ena le mathata?</i>	Student 2: Actually we have problem with this question?		
Student 5: Only question 4(b) is confusing?			
Student 2 and 6: <i>So potso e yona ena le mathata</i> because gare itse meaning of these words.	Student 2 and 6: Actually we have problem with this question because we don't know the meanings of these words.		

Question 5:

There is a wrong word in each of the following statement. Circle the wrong word and write the word which will make the sentence correct. Question 5 (a) has been answered to give a clue on what is expected.

5(a) When a water sample is heated, temperature is absorbed and therefore the temperature will increase.

Answer: Heat

5(b) The percentage of girls in a class of boys and girls is 200.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: 200 can't be a percentage. Therefore the wrong word is <u>percentage</u> , and the right word is <u>number</u> .		5(b) The wrong word is percentage.	Student 5 recognized that a percentage cannot be 200, but the number can be 200.

5(c) The temperature of a water sample can be calculated using a thermometer.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Calculated is the wrong word but measured is the right word.		5(c) The wrong word is calculated.	Students didn't struggle with this one, the answer was straightforward.

5(d) Since 100 grams of atmospheric air contains 21 grams of oxygen; we can deduce that the percentage of oxygen in air is 21 grams.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2 and 3: Also the wrong word is percentage.		5(d) The wrong word is grams student 3 and 4, and other group members said percentage is wrong.	Although the final answer was correct. Only students 3 and 4 agreed to change 21 grams to 21%. The other group members wanted to change the word "percentage" without giving their correct option. Students 1 and 6 were inactive.
Student 5: No, let us read the question again.			
Student 3 and 4: Oh Ok! Percentage can't be 21 grams, the word grams is wrong, meaning it should be 21%.			

5(e) The volume of a gas is 100 grams.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: The volume can't be in grams.		5(e) The wrong word is volume, volume is not in grams. The right word should be mass.	The students managed to link the first guiding word "volume" to its SI unit and knew that it cannot be in grams. Student 2 raised the question regarding the units used for volume which was a hint to the solution, and other students responded well by giving several
Student 2: Volume <i>kana ke eng</i> ?	Student 2: Tell me the units used for volume?		
Student 3, 4, 5 and 6: Stated several units for volume like ml, cm ³ , liter and dm ³ .			

Student 2: So the problem is the word volume the correct word is mass.			units. Nonetheless their option was also acceptable, that they said volume can't be in grams. Instead they said the wrong word is volume and right word is mass. Student 1 was inactive.
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Question 6

Convert the following statements into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statements (a).

6(a) The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a).

Answer: Variable quantities are R (resistance), l (length) and area (a), Equation: $R = k \frac{l}{a}$.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: It is simple and can't be tricky.		The language used is tricky, not easily understood.	Students agreed that the question was tricky for them, and they did not attempt it.
Student 5: E tricky, <i>akere wena</i> you are concentrating only on the first question, <i>rona</i> we are talking about the whole question 6.	Student 5: No it is tricky, isn't that you are focusing only on the first question 6(b), whereas we are talking about the whole question		

	6.		
Student 3: Ok, I understand, not all let's look at question 6(g). It needs lots of analysis before tackling or answering it.			

6(g) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided by the total mass of all the substances in the mixture.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 2: <i>Waitse ntho e nna</i> problem <i>kae</i> ? Because some of us <i>ga re itse</i> this thing <i>ya</i> inversely and directly proportional, when to put the signs $\propto$ or use equal signs?	Student 2: Do you know what causes the problem to answer this question? It is because some of us do not know the difference between inversely and directly proportional, when to put the signs $\propto$ or use equal signs?	The language used is tricky, not easily understood.	At the beginning student 3 indicated that the question was simple, but the group members disagreed and they decided to do question 6(g) There were several mixed responses regarding the question. Although the statement didn't have the words "inversely" and "directly" proportional, the student shifted their focus to these words, not attempting to answer the question but focusing on the example given. The question was not attempted but all members tried to clarify question 6(a). The students took about 10 minutes trying to understand the language used in the example. Student 1 was inactive.
Student3: <i>Maar ga bane bare bolella gore</i> it's directly proportional, it only needed that we include the constant <i>mo</i> equation <i>ya rona</i> . <i>Ga ke itse gore awa tlhaloganya gore ke raya jang</i> , like here referring to question 6(a).	Student3: I remember when they taught us, they said when something is directly proportional to the other we only include the constant after the equal sign in an equation, for		

	example look at question 6(a). I wonder if you get my point.		
Student 2: <i>O kgona go kwala jang</i> this thing of inversely proportional maybe (illustrating on a paper $1 \propto r^2$).	Student 2: How do you write this thing of inversely proportional maybe let us use $1 \propto r^2$ for an example?		
Student 3: Gave clarification using the equation (writing on a paper) $F = \frac{k q_1 q_2}{r^2}$, $F \propto q_1 q_2$ meaning is directly proportional, and $F \propto \frac{1}{r^2}$ means inversely proportional.			
Student 2: Confused by the signs, what do this sign $\propto$ mean, and when are we supposed to include the constant in the equation?			
Student 3 and 6: If something is inversely proportional you will see it as the denominator after this sign $\propto$.			
Student 4: <i>Fa o re</i> so, do we still add the constant before the sign or we add it when we have an equal sign?	Student 4: When you mention that does this mean that we add the constant before that sign ($\propto$) or only after equal sign?		
Student 3: No, constant <i>e tla fela fa go na le</i> equal sign, referring back to the equation F	Student 3: No, the constant is always written after an equal sign,		

$= \frac{k q_1 q_2}{r^2}$	referring back to the equation $F = \frac{k q_1 q_2}{r^2}$		
Student 5: So <i>maar kgang eke e botsang ke gore</i> , these are the sentences, and we need to convert them into equations.	Student 5: But my question is do we need to convert these sentences into equations?		
Student 3: All questions are fine but 6(g) is tricky, it doesn't have the same thing like other questions.			
Student 2: This is not tricky, the only thing we need to do is to understand the language, for instance <i>ba itse</i> , using 6(b) as an example the word "defined" does it mean divide or <i>e raya jang</i> ? Such that we can be able to convert into equation.	Student 2: This is not tricky, the only thing we need to do is to understand the language, for instance we are given 6(b) as an example, the word "defined" does it mean divide or what? Such that we can be able to convert this into equation.		
Student 5: I think we should generalize that the problem in question 6 is the language.			

Question 7

For each of the words/phrases given below, state its meaning in column 2 and the “opposite” word in column 3.

7(a) Constant quantity

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student3: First I don't understand this question.		Not understanding the question, because our groups members tend to write the meaning of the opposite word and not the original word.	Although they stated their confusion in the final answer, it showed that during their conversations students tried to answer the question. Student 5 had more understanding than the rest of the group, whereas student 2 showed she was lost. Student 5 tried to clarify and answer the question. Students 1 and 4 were inactive in this question.
Student 5: <i>A wa re gao tlhaloganye?</i>	Student 5: Are you saying you don't understand this question?		
Student 3: Yes the whole question I'm lost!			
Student 5: What you have to do for each word below, state its meaning. Like what does it mean? And after saying the meaning give the opposite word?			
Student 3: Constant quantity-it means it doesn't change but remain the same.			
Student 5: So if it changes <i>e raya gore</i> opposite word is variable. <i>Akere</i> you know a constant never changes, but a variable <i>e phela e</i> changer?	Student 5: So if it changes it means the opposite word is variable. Isn't it that you all know that a constant never changes, but a variable keeps on changing?		
Student 2:	Student 2:		

<i>Kante re tshwanetse re dire eng mo potsong e?</i>	Actually what are we supposed to do in this question?		
Student 6: Give the meaning of the original word given, and thereafter give the opposite of the original word?			
Student 2: <i>Ijoo!!</i> Honestly <i>haai nna</i> this question is difficult for me!	Student 2: Really to be honest this question is difficult for me!		

7(b) Absorption of heat.

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: It simply means endothermic.		Not understanding the question, because students tend to write the meaning of the opposite word and not the original word.	Students failed to put much effort into this question and did not come with ideas. They even failed to see that the word endothermic was given later in the question. Only student 3 attempted to answer the question. Students 1 and 4 were inactive.
Student 5 and 6: No it is not.			
Student 6: The problem will be students not understanding what the question is asking for? Because most people will write the meaning of the opposite word not giving the meaning of the original word			
Student 2: This means we are unable to interpret the question.			

Question 8

Two cars, 160 km apart on a main road, travel towards each other. The first car travels for 20km and takes a right turn and travels for 15 km. It then turns left and travels for another 30km, and then turns left again and returns to the main road. In the meantime, the other car travels 40 km along the main road.

- (i) Represent all the information given above as a diagram.
- (ii) What would be the distance between the two cars?

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 3: Guys this question is straightforward.		3 Students do not understand why the 15 kilometres cannot be accounted for when doing the calculations 1 student does not understand the axis of the distance, which is head to head collision or is it left and right collision.	Again student 5 gave the group a hint that drawing a diagram is the option to answer the questions. He tried to show how these cars move from opposite directions on a piece of paper. Students 2 and 3 were confused, as they were asking student 5 to indicate the scale. He tried to clarify, but the major confusion arose when car A turned right and left. The 15 km was a serious problem; they failed to realize that this was traveled at right angles to the second car. They ended moving far from the answer asking if both cars ended up colliding. Students failed to understand and
Student 5: In this question you simply need to analyze the question and draw the diagram.			
Student 3: Thereafter calculate the distance.			
Student 6: But the problem will be here referring to question 8(ii).			
Student 2: How do we do this <i>maar</i> ?	Student 2: But how do we do this?		
Student 5: Illustrating using hand, the movement of two cars from opposite direction.			

Student 2: I want to see the diagram.			interpret the question. Students took 15 minutes but failed to reach a conclusion. Student 1 did not participate in this question.
Student 3: Draw the diagram and asking for the scale.			
Student 5: No scale is required, the important thing is to draw the correct diagram.			
Student 6: No the diagram is incorrect referring to student 3, you cannot draw up and down, the statement said on a straight line from left to right. Did the first car stop somewhere?			
Student 3: They never mentioned if it stopped or what?			
Student 4: Kante di ntshang , are we not adding all the distance covered by car A, because distance is not a vector?	Student 4: Actually what is happening, are we not adding all the distance covered by car A, because distance is not a vector?		
Student 5: Broer let me explain this situation, (illustrating with hands). We have car A and car B, one is moving from this direction the other is moving towards this direction.	Student 5: Brother let me explain this situation, (illustrating with hands). We have car A and car B, one is moving from this direction the other is moving towards this direction.		
Student 6: This 15 km is the one causing confusion,			

why is it not included when doing calculation of the distance between two cars?			
Student 4: This 15 km <i>ke mathata mo go nna</i> .	Student 4: This 15 km is a serious problem to me.		
Student 3 and 6: Drawing and calculating on a paper trying to show student 4 why 15 km cannot be part of the calculation of the distance between two cars.			
Student 4: <i>Oook!</i> This means <i>re batla</i> distance <i>ya</i> on the main road, <i>eseng ya go chika-chika</i> ?	Student 4: Now I get you point! This means have to calculate distance travelled on the main road, not the one when the car keeps on turning to the left or right?		

Question 9

This question concerns the masses of 5 objects A, B, C, D and E. The mass of A is larger than the mass of B by 4g but is smaller than mass of C by 2g. The mass of D is smaller than the mass of A by 2g but is larger than mass of B. Object E has the largest mass of 10g.

- Which object will have the smallest mass?
- Arrange all the objects in order of increasing mass (i.e., start with the object that has the lowest mass).

Actual voice recording (Using mixed languages)	Translated English phrase	Group Final Conclusion (Written Answers)	Summary regarding the students' deliberations:
Student 5: Trying to use masses, wrote $A = B + 4g$ to find the smallest object.		9(a) Object B. 9(b) Object B = 2g, Object D = 4g, Object D = 6g Object C = 8g and Object E = 10g.	Student 5 managed to give the right answers and student 4 gave incorrect equations. Student 2 was confused and they tried to explain it to her. They finally got the right answers. In this question students 1, 3 and 6 were inactive in answering the question.
Student 4: No it is $A = B - 4g$ and $A = C + 2g$.			
Student 2: <i>Heish nna ke mathata!</i>	Student 2: Honestly I'm lost.		

In Questions 10-22:

Students did not attempt to answer these questions

4.25.2.1 Group two general findings:

The group had 6 members. Students chose to start with question two like the first group, as the instruction said they must discuss questions which gave them difficulty during individual pre-test question paper. In question 2, students did three sub-questions 2(a), 2(b) and 2(d). They answered all the sub-questions correctly and also gave reasons for their choice of answer, in which the 2013 group failed to do so. But during their conversation some students were confused and others within the group clarified the difference to them and also spoke how the words differ from each other regarding their use.

In question 3, students attempted to answer only sub-question (b) “a liter of water is heavier than a liter of ethanol”, and they clarified to each other correctly, and used a different example to elucidate more to other members saying “her material is stronger than mine”. The students mentioned in their answer that they understand the difference between the words.

In question 4, students answered sub-question (a) and (b), and they gave correct answer for only part (a). In part (b) students struggled to come up with the correct answer, the statement was a “theoretical statement” and they gave three different incorrect responses, that it was an “opinion” or a “fact”. One student was correct saying it was a theoretical statement, and further clarified using “Newton’s law”.

In question 5, students answered sub-questions 5(b)-5(e), and answered all the sub-questions correctly. Although in both parts (b) and (c) only two students discussed and gave the correct answers. And in part (e) students even gave several units used for volume.

In question 6, students answered questions 6(a) and 6(g). In both sub-questions students had varying answers, with the first one to answer indicating that the question is simple, and other group members disagreed that not all questions are simple, and wrote the final answer as “language used is tricky and not easily understood”. In part (g) students were confused and

ended up using wrong examples which were not part of the question, mentioning they are confused by the words “inversely and directly proportional”, with students 3 trying to clarify to them using the equation $F = \frac{k q_1 q_2}{r^2}$, $F \propto q_1 q_2$ meaning is directly proportional, and $F \propto \frac{1}{r^2}$ means inversely proportional. Although this was good, they did not touch what was required from the question asked.

In question 7, the students answered sub-questions (a) and (b), they were required to give the opposite phrase of the words given. They answered only two parts and in part (a) the word “constant quantity” students were not sure on what was expected from, although one student gave the correct answer that the opposite word is a “variable quantity”, others ended up disregarding his answer. For part (d) In part (b) the word “absorption of heat” confused the word and just gave an example of the reaction in which heat is absorbed which is “endothermic”, this showed that he had some understanding on the use of the word. And in their final answers students wrote that they did not understand the question as some students gave the meaning of the opposite word required.

In question 8 students failed to answer both sub-questions, firstly they failed to draw the diagram, stating confusing clarifications, other asking for “vectors”, also if the first car had stopped somewhere. Secondly they failed to do the right calculation, and asked why the 15 km cannot be included in the calculation, although student 5 told them to do the analysis, and even tried to clarify to them how the two cars moved, with one student asking if the cars had collided. Student were confused in answering this question correctly

In question 9, students managed to identify the object with the lowest mass, and also able to arrange all objects in order of their increasing mass. Students didn't struggle in answering this question correctly

A combined summary of the implications of this stage, including both groups will be discussed on the following section.

4.26 General findings: (student-student interactions)

The students were given time to interact with each other, so that they could share their understanding and try to agree on answers, based on their own learning styles. The author recognized through recordings that some students were not interested and did not actively participate, while others grappled with the problems.

In the descriptive and explanatory statements students' discussions indicated that students struggled with understanding of the meanings of these words and gave wrong answers. For example statement 2(f) "In a neutral atom, the number of electrons is equal to the number of protons", the students struggled and indicated that it is an "explanatory statement" because it explains what is basically inside the neutral atom after they used their mother tongue clarification. They did not focus on the definitions of the words. Some students amongst the groups were on the right path giving correct answers but their opinions were not taken into cognisance by other group members. Some members of the group did not participate in the discussions. The 2014 group took a longer time than the 2013 group, although they answered fewer questions, and they answered most of the questions correctly. The 2014 group were more focused and used several other examples to elucidate problems to each other. The other issue is that both groups switched to their mother tongue (Setswana) to assist in answering questions, this code switching caused difficulty particularly in the 2013 group whereby some students' interpretations of the use of the words "descriptive" and "explanatory" led them to give wrong answers. Whereas in the 2014 group this code switching assisted them to give right answers, which shows that the use of multi-language during small group discussions can assist some students to clarify their difficulties in questions causing problems to the others,

this is in agreement with studies done by Owen-Smith (2010). This will help students to develop their self-esteem and confidence when interacting with each other.

One student said that the lecturer had explained in class but wished she had used more examples on descriptive and explanatory statements. This statement indicates that there is a gap between how the instruction and facilitation is done to these students' which affects their ability to cope, in chemistry. As facilitators we need to focus not only in the completion of the curriculum, but must also assist students to grasp fundamental concepts of understanding the language used in chemistry, and how to use their memories in developing their cognitive abilities. This is in agreement with what was suggested by Johnson (1997), that students must be assisted to develop thinking strategies such as self-monitoring, and evaluation of their work also to avoid overload of the working memory as suggested by Sirhan (2007).

In the qualitative and quantitative statements, in the 2013 group, one student tried to differentiate between these statements by indicating that quantitative statements can be expressed in the form of equations. Although they were able to define the words correctly, they were unable to apply the definitions. One student was correct, but other members of the group indicated that they were still confused. In the statement "A litre of water is heavier than a litre of ethanol" students gave wrong answers, with some saying the word "heavier" refers to the mass or weight which can be measured. The group failed to recognize that this was a qualitative statement. The 2014 group wrote that they understood the question although their audio conversations suggest that some students did not understand the meanings of these words and only agreed to please their classmates, and possibly to avoid having to apply mental effort to answer the questions. The other issue which caused difficulty for students was their attitudes. Throughout their conversations, some members were not attentive, did not show interest and lacked discipline. As suggested by Xu and Lewis (2011), if students have

negative attitudes about the tasks they will put less mental effort in answering the questions correctly.

In question 4 the 2014 group gave better responses than the 2013 group, but the students failed to reach amicable conclusions, with some indicating that they were unable to understand the meanings of the words mentioned.

Question 5 required students to identify wrong words in sentences given. Both groups tried to answer the question correctly. Some members of the group gave correct responses but were ignored by their group mates and they ended up writing wrong answers. One student commented that if she knew the meaning of the words, she would do better in chemistry or even score distinctions, which is in agreement with findings from Oyoo (2011)

Question 6 required students to identify variable quantities and also write equations. In the 2014 group students indicated that the language used was “too tricky” although some students disagreed. The 2013 group tried to answer the question but failed to do the first part of identifying variable quantities. However they gave correct equations in some questions although they failed to include the units, showing that they did in fact know what the variables were. The group took about 12 minutes and made more effort to solve the problems than the 2014 group. One group member pointed to the problem, saying “I can’t believe that such simple things made us fail, this means we just rush to answer without first trying to understand the question”. Another student pointed out “it is because some of us do not know the difference between inversely and directly proportional, when to put the signs $\propto$ or use equal signs”. These students’ statements also proved that students sometimes put less mental effort resulting in their high failure rate in chemistry.

Question 7 required the students to give the meaning and opposite phrase of the words given. The 2014 group indicated that they did not understand the question because some group

members gave the meaning of the opposite word and not the original word. One student amongst the 2014 group could give correct answers and explain them, but other group members did not take him into cognisance. The 2013 group made an effort to answer almost all parts in this question, although some answers were incorrect. Student 2 showed more understanding and explained to other group members, and also mentioned that language is a problem, but that some things become clearer when discussed in the group.

Question 8 required students to do calculations and also represent information from verbal statements as a diagram. In the 2013 group only students 2 and 5 were active, and tried to give answers, although their diagrams and calculations were incorrect. In the 2014 group the students took more time trying to work out the correct answers, with student 5 giving better clarification to the other members, although other students were confused. The confusion became more when they calculated the distance between the two cars. Some did not understand why the 15 km travelled by car A was not part of the calculation. They failed to reach a conclusion in this question.

In question 9, in the 2014 group, student 5 again took the lead, and assisted by student 4 gave correct answers, although student 2 indicated that she was lost. The other group members were inactive. In the 2013 group only student 2 gave the answers, part (a) was correct but part (b) was incorrect. Other group members were inactive.

In question 11, students were required to identify variables and do calculations. Only the 2013 group answered the question, although they took time and referred to question 6, they failed to answer this question correctly.

Question 8, 9, and 11 tested the ability to draw conclusions from the verbal statements, by either using a diagrams or doing calculations. The results showed that students lacked the

cognitive abilities such as; constructing meaning, evaluating the text, distinguishing between important points in the text towards reaching logical conclusions.

Both groups indicated that questions, 10 and 12 to 24 were simple, but their pre-tests results did not support their conclusion as the performances were low in some questions. They may have become tired and unwilling to apply further effort in answering these questions. These results indicated that students need assistance, using their own learning styles, on how to gather information in order to understand the meanings of some words in terms of language and verbal reasoning. The findings for both the pre-test and student-student interactions will be used to guide the facilitator-student interactions in the intervention programme

4.27 Chapter summary

This chapter discussed students' performances in the pre-test to check if there was a significant statistical difference and also the student-student interactions transcribed audio recordings between the groups and how they answered the questions. The difficulties in language skills and verbal reasoning skills, encountered by students during the pre-test and SSI, will be used to guide the remedial instruction program. The next chapter will discuss how the intervention programme (IP) was conducted.

CHAPTER 5

INTERVENTION PROGRAMME (IP)

5.1 Introduction

This chapter discusses the intervention program during the period (April 2015). The solutions to some of the pre-test questions were discussed. Active participation by students was encouraged in a venue which allowed free movement amongst the students and the facilitator. Wi-Fi was accessible. The students divided themselves into four groups with five members each. Each student was labelled with two numbers, a number (1-4) to label the group, and a second number (1-20) to label him/her.

The aim of the program was to help and guide the students so that they could correctly answer some of the pre-test question paper.

5.2 Facilitator-students intervention (FSI) session

Initially 39 students participated in the program but only 20 of them participated in all the three weeks sessions of the program.

The facilitator used the dialogic approach for the intervention. Bloom's lower level domain (cognitive abilities) and the kinesthetic learner model were used for the intervention (Sprenger, 2008) which is consistent with the constructivist approach. The kinesthetic learning model places emphasis on how students reflect and connect. The process requires touch, movement, and team-work. Two technicians in the department helped as scribes during the intervention program. The facilitator used several instructional methods during the

intervention. It included power-point presentations, document-camera presentations and some simple experimental procedures. The following instructions were given to the students.

Instruction to students: Each student has to contribute during the discussion in rotation when presenting questions on the board, doing hands-on activities or using the document-camera.

Bloom's (1956) taxonomy will be used, as shown in figure 5.1

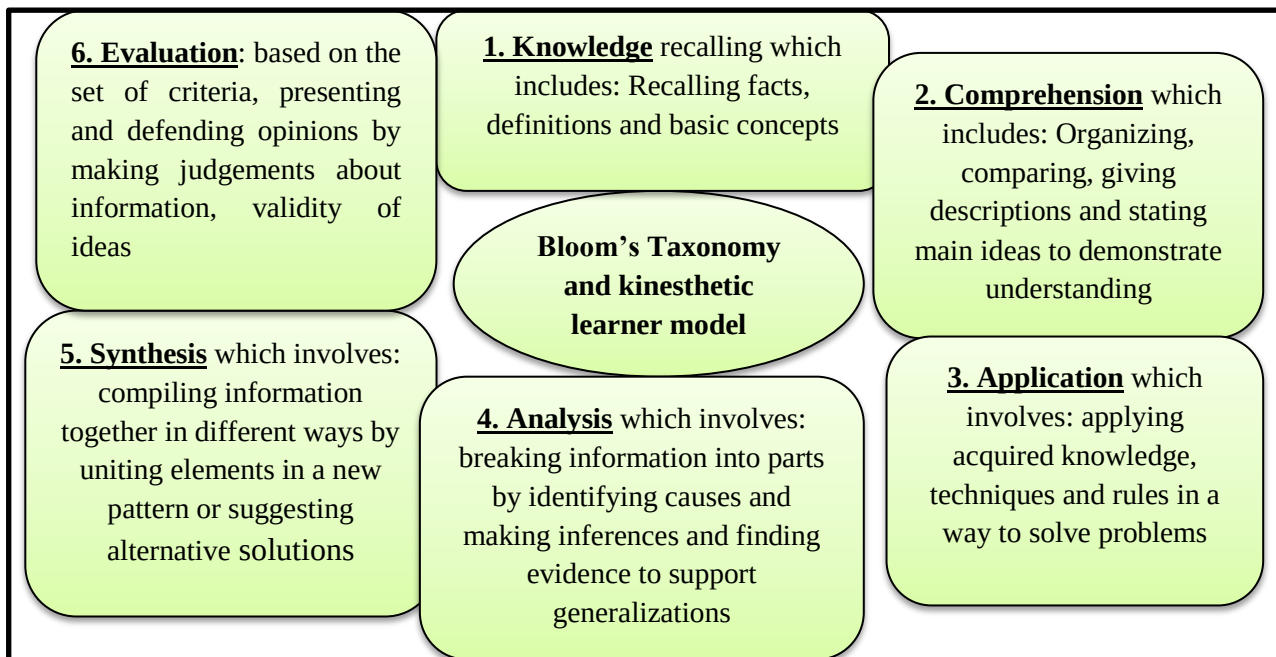


Figure 5. 1 Bloom's (1956) taxonomy

The facilitator stated that students should answer their questions using the terms below whenever necessary, using Bloom's taxonomy:

1. Knowledge – this level includes words like; who, what, why, when, where, how, define, match and relate;
2. Comprehension – this level includes words like; compare, contrast, demonstrate, interpret, explain, extend, illustrate, summarize, show and classify through physical interpretation;

3. Application – this level includes words like; apply, choose, construct, develop, experiment with, plan, select, solve, and identify;
4. Analysis – this level includes words like; analyze, categorize, divide, examine, classify, compare, contrast, simplify, distinguish and conclusion;
5. Synthesis – this level includes words like; build, choose, combine, compile, create, design, estimate, solve, discuss, and elaborate;
6. Evaluation – this level includes words like; choose, conclude, decide, determine, measure, compare, and prove.

Question 1

This question tests understanding of the non-technical words and phrases given in column A below, which are frequently used in chemistry.

Match these words to the phrases/statements in column B.

Facilitator: Let us look at question one, it has the term “non-technical” words. What does this word “non-technical” mean? <i>(The students were required to discuss amongst themselves and give their final answer).</i>				
Group responses:	Group 1	Group 2-	Group 3	Group 4
	These are words not used only in experimental activities but applied in other courses;	These are words used in other science courses including chemistry;	To be honest the word “technical” is tricky to reach conclusion	These are words that are not technical but used normally
Facilitator: The “technical words” in science refer to words which are specific to the science context and serve a more specialized purpose. Whereas “non-technical words” are words which are also used both in an everyday context and in some cases tend to assume a more specialized meaning when used in science contexts. For example the word “reaction” in normal everyday language means ‘something done, felt or thought in response to a situation or event. But in chemistry it is a chemical process in which two or more substances combine to form new substances. Facilitator: Do you all understand? Or maybe someone can give an example?				
Group responses:	Group 2-		Group 4	
	Student 2: Mam I think now I get a point; these are words that can be used both in everyday normal language and in science context.		Student 1: I can say that “reaction” it is a physical nature, for example I have not paid the rent, and the landlord’s reaction is to give me the final notice to move if I don’t pay.	
Facilitator: Tell me the meaning of the word “reaction” used in chemistry context?				
Group responses:	Group 1			

	Student 4: “A process in which atoms of the same or different elements re-arrange themselves to form new substance, while they do so they absorb heat or give it off” (Online dictionary.com).			
Facilitator: Thanks for your response. Now write which level will best fit question 1, using the hierarchy levels as shown on the screen, and give a reason for your choice				
Group responses:	Group 1	Group 2-	Group 3	Group 4
Each group wrote their answers on the board. The summaries for the groups were as follows;	Knowledge level- The word “match” as given in the question helps us to recall definitions of the words and match them with the correct phrase;	Knowledge level-The word “match” because it helps us to choose words which best fit the correct definition or phrase in column B;	Knowledge level,-Match is the right word because we can match words in column A with their definitions in Column B;	Knowledge level-The question said “match” words in column A with phrases in column B.
Facilitator: It seems we all agree that question one requires us to recall, so it is very important, to understand the meanings of some words before attempting the question. Is there anyone who needs assistance?				
All Groups: Agreed to move to the next question, as they understood question one.				

Question 2

Which of the following statements are **descriptions** and which are **explanations**? Briefly give reasons for your answers.

Facilitator: This question asked about descriptive and explanatory statements, each group must write their understanding of these two words. Also indicate the level from Bloom's taxonomy.				
Group responses:	Group 1	Group 2-	Group 3	Group 4
	Descriptive it just tells you, whereas explanatory is answering the question why, it has words like because? It is comprehension level;	Description indicates how something looks like and explanation it answers why that thing looks like that. It is Comprehension level	Description saying something as it is and explanation why something behaves that way. It is comprehension level	Descriptive gives an overview but explanatory goes further and further. It include both knowledge and comprehension levels.
Facilitator: Let us take three examples questions 2(b), 2(c) and 2(e); indicate which statements are descriptive and which are explanatory? State reasons for your choice. 2(b) The percentage of oxygen in the air is 21% 2(c) An electric current passing through a metal is due to the flow of negatively charged particles (electrons). 2(e) In a neutral atom, the number of electrons is equal to the number of protons				
Group responses:	Group 1	Group 2-	Group 3	Group 4
	2(b) It is descriptive – it tells only about the percentage of oxygen in the atmosphere. 2(c) It is descriptive – it only tells us about the flow of negative charges in a metal. 2(e) It is Explanatory – because it goes in more details clarifying what is inside the atom.	2(b) It is descriptive – it gives the percentage of oxygen 2(c) It is explanatory – it gives reasons why there is an electrical current, because of the flow of electrons. 2(e) It is explanatory – it goes further telling the number of electrons and protons inside the atom.	2(b) It is descriptive – it just tells us how much of oxygen is in the atmosphere in terms of percentage. 2(c) It is explanatory – the word “due” clarifies the cause of the flow. 2(e) It is descriptive – it only tells us what it is inside the atom.	2(b) It is descriptive – it says how much oxygen is in the atmosphere. 2(c) It is explanatory – it goes further in clarifying why there is an electrical current in the metal because of the flow of electrons inside the metal. 2(e) It is Descriptive – it states what is inside the atom, which

				is a fact.
Facilitator: Using definitions provided in the first part of this question by individual groups, which groups gave the correct answers?				
Group responses:	Group 1	Group 2-	Group 3	Group 4
	Student 3: I think Group 3 and 4 are correct although I will go with reasons provided by group 4.	All agreed with student 3 in group 1.		
Facilitator: Group 1; Student 3: Why did you choose options given by other groups instead of that given by your group?				
Group 1: Student 3: Mam, the problem is that we are still disagreeing to write our final answers, some students want think they know better than other, and only their answers are supposed to be correct.				
Facilitator: It is not wrong to disagree but the group work is not for an individual response, discussion and clarity will assist your group members to understand your point of view.				
Group 4: Mam we include knowledge level because it has words like how and why. Also comprehension level because it has the word explain.				
Facilitator: A descriptive statement presents how things are and explanatory statement gives an account or reasons why something is like that in terms of properties of particles present.				
All groups: Indicated that they understood.				

Question 3

Which of the following statements are **qualitative** and which are **quantitative**? Briefly give reasons for your answer.

Facilitator: This question asked about quantitative and qualitative statements.

Let us do these activities:

Activity one: On the front bench we have two beakers, beaker A and beaker B, containing two different liquids. You must work in pairs, one student has to lift both beakers and place each on the other student's hands. This must be done silently, after each member has held both beakers, then return to your benches. On top of your benches you will find two folded papers of different colours for each student, unfold the yellow paper, and make sure your group member doesn't see what is written inside. Secretly answer the question, fold back the paper and drop it inside the small yellow marked beaker.

Activity two: Go to the weighing room; take along the other folded green paper. Weigh each beaker separately containing the liquids A and B, and record the mass secretly on the green paper, thereafter return to your bench and drop the folded paper inside the green marked beaker on your bench.

Discussion

Facilitator: Reading the questions

1. Yellow paper: Beaker _____ is heavier than beaker _____.
2. Green paper: The mass of beaker _____ is _____ and larger than the mass of beaker _____ which is _____.

Facilitator: Let us unfold the papers per bench, starting with group 1- group 4.				
Group responses:	Group 1	Group 2-	Group 3	Group 4
	3 Students beaker A is heavier than beaker B. 1 Student beaker B is heavier than A	All Students beaker A is heavier than beaker B;	All Students beaker A is heavier than beaker B;	All Students beaker A is heavier than beaker B;

Facilitator: which activity represented a qualitative observation and which represent a quantitative observation? Anyone is allowed to give his/her opinion.

Group responses:	Group 1	Group 2-	Group 3	Group 4
	Student 1: “Mam to be honest this thing of quality and quantity I am lost” Student 2 “mam I think quality has no units and quantity has units”.	Student 1: “Mam in our group we think touching the beaker is quality and weighing them is quantity”.	Student 3: “Mam in our group we say the activity of sensing with our hands also the question in the yellow paper was qualitative, whereas weighing both beakers and recording their masses was quantitative”.	Student 3: Qualitative is the one written on yellow paper, and quantitative is the one written on green paper.

Facilitator: Let us assist group 1 and the rest of us to understand the difference between quantitative and qualitative statements. Use online search and cite the sources.

Group responses:	Group 1	Group 2-	Group 3	Group 4
	“Quantitative data is numeral, and qualitative data uses words to describe something” (<i>Google statistics answers</i>).	“Quantitative describes a statement or analysis, which gives the amounts of an item”. Qualitative observation involves the quality of something such as colour, shape, texture and etc. (<i>Random House Kernerman Weber’s College dictionary</i>).	“Quantitative capable of being measured” whereas qualitative cannot be measured (<i>Collins English dictionary</i>).	Quantitative “capable of being measured” (<i>Collins English dictionary</i>). A qualitative statement is text-based analysis that is comparative and does not involve units of measurements (<i>Google search-Rhiana Quick</i>).

Facilitator: Quantitative analysis determines the amount and proportions of the chemical constituents of a substance or a mixture. Quantitative means numbers and measurements e.g. Mix two moles of hydrogen and one mole of oxygen and you get one mole water (*Eric Jones*). Qualitative analysis determines the chemical constituents of a substance or mixture. Qualitative does not have measurements e.g. mix hydrogen and oxygen to get water (*Eric Jones*).

Facilitator: Is it ok or is someone struggling?

Group responses:	Group 1	Group 2-	Group 3	Group 4
	Student 5: Sometimes I wish they could allow us to use dictionary or internet to see the meanings of these words during tests and exams. Look how easy it is to understand now.	This is so true Mam why?		
Facilitator: Learning is a process; remember that examinations rules don't allow any use of notes or textbooks. Hence it is very important to understand the concepts properly and also to keep up to date with the scientific vocabulary. Let us do the following questions together, and indicate which is qualitative and which is quantitative? (a) The density of a substance is the mass per unit volume. (b) A litre of water is heavier than a litre of ethanol. (c) Ice melts at 0 ⁰ C.				
Individual responses:	Student 1 (a) is quantitative, because it can be written in a form of an equation	Student 5 (b) is qualitative, and it is similar to what we did in the activity, when we use our hands to sense which beaker was heavier than the other	Student 11 (c) it is quantitative, is has a numerical value.	
Facilitator: Is there anyone still confused All students: Agreed that they understand. Facilitator: It is very important to recall and connect; it is not advisable to cram these words but to familiarize yourselves with them and use practical activities to assist in clarification. In class have your own vocabulary book, and ask if you don't understand, this will help in developing improved study skills.				

Question 4

Consider each statement given below and state whether it is best considered to be an experimental **fact**, a **law**, an **opinion**, a **definition**, or a **theoretical statement**. Make comments to justify your answers.

- (a) The temperature at which water boils is 100°C .
- (b) Water dissociates to form H^{+} and OH^{-} ions.
- (c) Effusion is the escape of a gas through a small hole.
- (d) The total mass of a system remains constant during a chemical reaction.
- (e) Density is mass per unit volume.

Facilitator: Let us do the following activities: a. There are two balloons per bench, inflate both balloons (make sure it is not fully inflated) and tie both of them with different strings, then use a needle to pinch one of the balloons. Wait for 2 minutes and note the difference between the balloons. Press the other balloon with your hand for one minute. b. Balance the following acid-base reaction: $\text{KOH}(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{K}_2\text{SO}_4(aq) + \text{H}_2\text{O}(l)$ Facilitator: Group 3, give us your results.		
Group responses:	Group 3 a. The pinched balloon started to decrease in size slowly and the other balloon was also releasing the air slowly when pressing it. b. $2\text{KOH}(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{K}_2\text{SO}_4(aq) + 2\text{H}_2\text{O}(l)$	
Facilitator: How can you link activities (a) and (b) with any part of question 4?		
Group responses:	Group 3	Group 4
	Student 5: What do you mean by definition? This is an experimental fact. (referring to student 4 in group 4)	Student 4: Mam (a) showed that the gas inside the balloons was slowly escaping, therefore it answers the question 4(c) and it is a definition.
Facilitator: Let us clarify this, or maybe ask student 4 in group 4 why she is not agreeing with the other student?		
Individual response	Group 4; Student 4: Here we were actually trying to understand what effusion is by experimenting using balloons. But the statement in 4(c) gives a definition of effusion.	

Question 5

Facilitator: In this question the groups will be doing question 5(b until 5(e). Thereafter each group will project their answers using the document-camera.

There is a wrong word in each of the following statements. Circle the wrong word and write the word which will make the sentence correct. Question 5 (a) has been answered to give a clue what is expected.

5(a) when a water sample is heated, temperature is absorbed and therefore the temperature will increase.

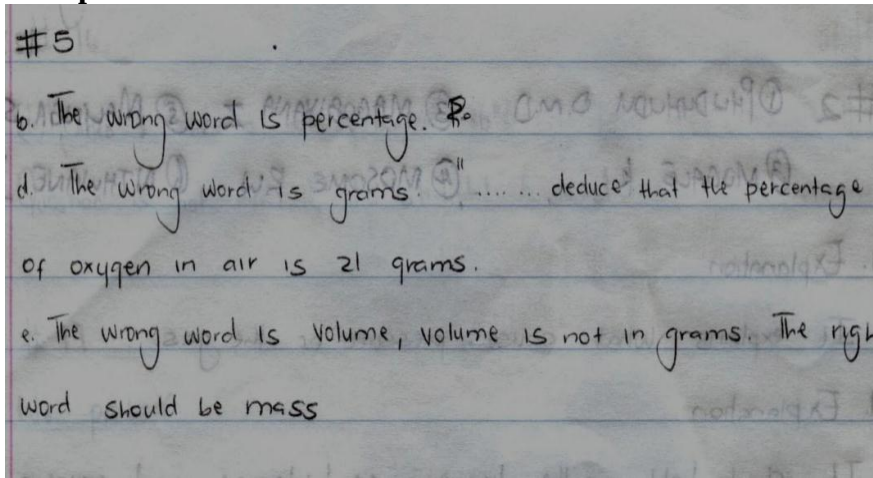
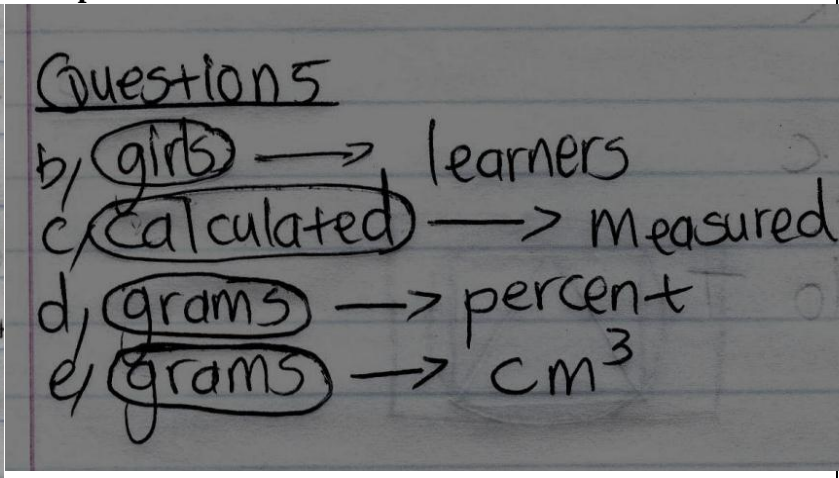
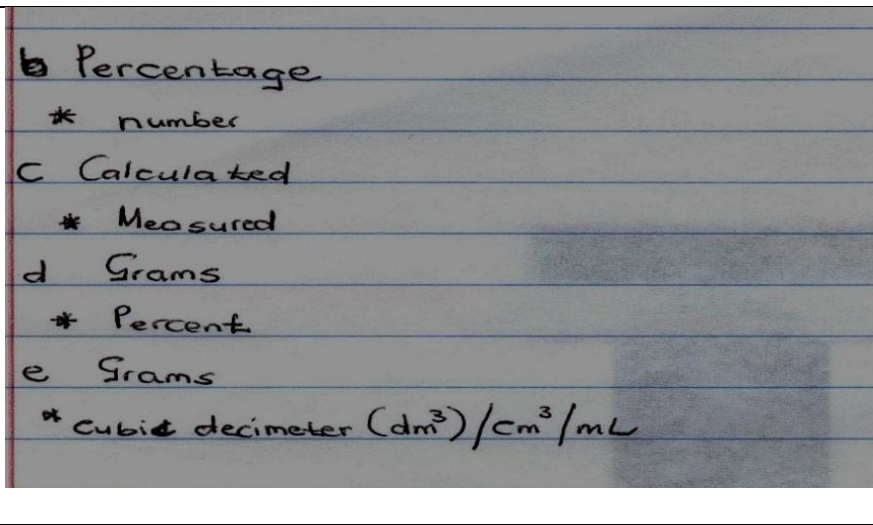
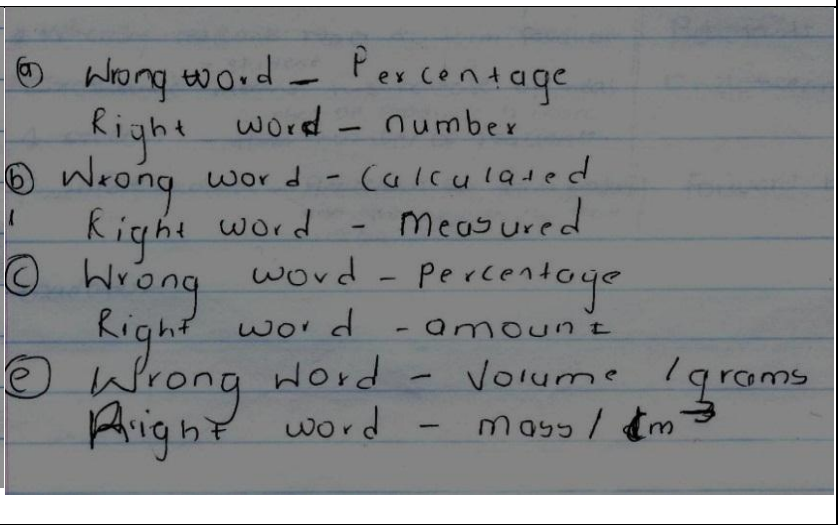
Answer: Heat

5(b) The percentage of girls in a class of boys and girls is 200.

5(c) The temperature of a water sample can be calculated using a thermometer.

5(d) Since 100 grams of atmospheric air contains 21 grams of oxygen, we can deduce that the percentage of oxygen in air is 21 grams.

5(e) The volume of a gas is 100 grams

Group responses :	Group 1	Group 2-
	 #5 b. The wrong word is percentage. # d. The wrong word is grams. ... deduce that the percentage of oxygen in air is 21 grams. e. The wrong word is Volume, Volume is not in grams. The right word should be mass	 Questions 5 b, <u>girls</u> → learners c, <u>Calculated</u> → measured d, <u>grams</u> → percent e, <u>grams</u> → cm^3
	Group 3	Group 4
	 <u>Percentage</u> * number <u>Calculated</u> * Measured <u>Grams</u> * Percent <u>Grams</u> * cubic decimeter (dm^3)/cm^3/mL	 a) Wrong word - Percentage Right word - number b) Wrong word - calculated Right word - measured c) Wrong word - Percentage Right word - amount e) Wrong word - Volume / grams Right word - mass / dm^3
Facilitator: I can see numbering is a problem here. Question 5(b) three groups said the wrong word is “percentage”, with two groups mentioning the right word as” number” and one group didn’t give their correct word. One group said the wrong word is girls and the right word is learner.		

Facilitator: What was the problem with this question?			
Individual Responses	Student 3: Mam percentage can't be 200, at least number sound better?		
Facilitator: Group 2, your answer is different from other groups; you said “girls” is a wrong word and” learner” is the correct word. Does this mean that boys are not learners?			
Individual Responses	Group 2; Student 1: Yes Mam they are also learners. Group 2; Student 5: Mam you know percentage can't be 200, according to me the wrong word is 200, because percentage of girls can be less than 100 but not more. We disagreed when writing the final answer.		
Facilitator: I said teamwork, and how you analyze the question and bring ideas to reach a common conclusion is very important. The answer you gave is correct; percentage has to be equal to or less than 100..			
	Group 1; Student 5: It is true Mam		
Facilitator: I can see 3 groups answered 5(c) correctly except for group 1 did not answer the question, why?			
	Group 1; Student 1: Mam we thought we only do those difficult to us, but we agree with the other group's responses.		
Facilitator: Thanks but next time follow the instructions, some things might look simple to someone within a group whereas this might be untrue to other members. Question 5(d) I can see different responses. Any volunteer?			
	Group 1; Student 1: Mam we wrote the wrong word as grams, and did not include the right word and that it must be 21 percent.	Group 2 and 3: Our answers are the same as given by the group 1.	
Facilitator: Group 4, you said wrong word is percentage and the right word is amount, what do you mean by amount?			
	Group 4; Student 1: This refers to how much of oxygen in the atmosphere which is 21 grams.	Group 1; Student 3: Mam I want to ask the group a question that do they refer to mass when using the word amount?	Group 4; Student 3: Yes we meant that.
Facilitator: In chemistry what do we mean by amount of substance?			

	Group 1; Student 3: We refer to the number of moles Mam.
Facilitator: that's correct, in chemistry the amount of substance does not refer to the mass or volume of a substance, but it refers to the number of moles	
	Group 3; Student 5: This word is also having a double meaning Mam, in normal everyday language it means total value of something like in terms of money, but in chemistry it has a different meaning.
Facilitator: Thanks, it seems now we are becoming clearer about these language problems.	
	Group 1; Student 2: But it need serious time even when teaching give us the meanings at least.
Facilitator: I agree that as instructors we must give guidance, but also as a student you must play your role by asking questions and doing small group studies.	
	All groups: Agreed to move to the next question.

Question 6

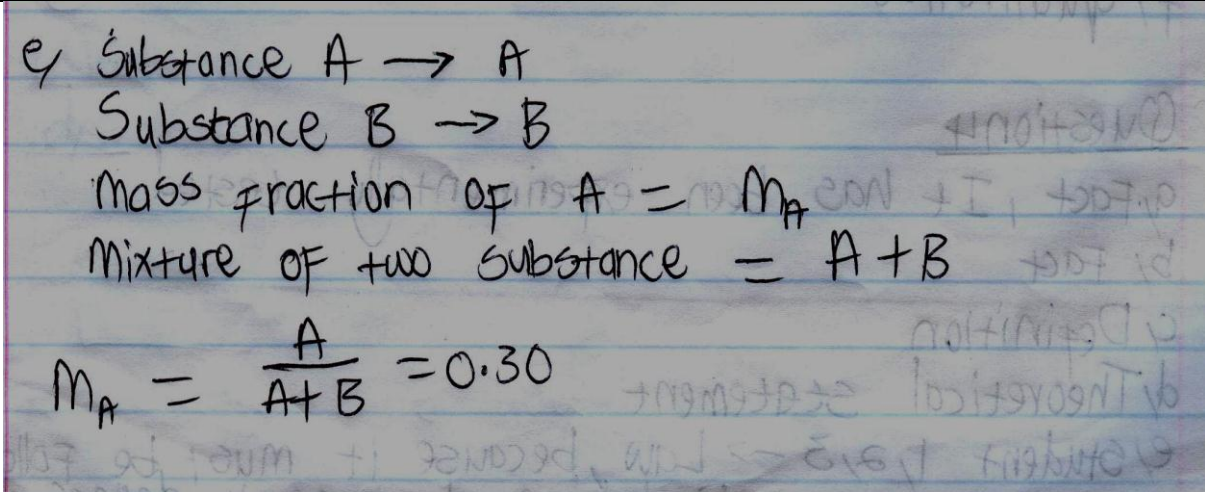
Convert the following statements into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statement (a).

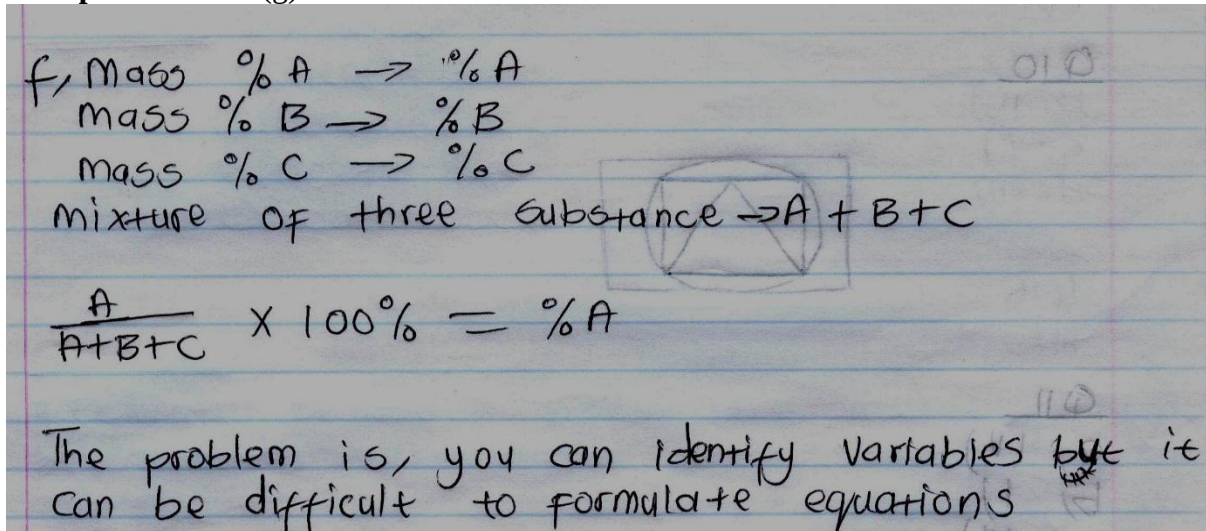
- a. The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a).

Answer: Variable quantities are R (resistance), l (length) and area (a),

Equation: $R = k \frac{l}{a}$

Facilitator: Can anyone clarify what this question requires us to do? Here we need individual responses			
Individual responses:	Student 8: Mam the word “variable quantities” is confusing.	Student 12: No Mam it is not confusing let student 8 read the question slowly and try to figure out from the example how the question must be done.	Student 8: I still don’t understand the word variable.
Facilitator: Can we go back to question one, and check the phrase which matched the word “variable”.			
Individual responses:	Student 2: “Mam I think a variable is not something constant, it keeps on going up and down.	Student 3: What do you mean by up and down?	Student 2: I mean it is not stable.
Facilitator: Ok thanks for your contributions, but let us go back to question 1, and see the phrase that matched this word variable to assist student 8.			
Individual responses:	Student 5: The right phrase is “a quantity whose value can change”.	Student 6: Mam can’t we do some sub-questions in question 6?	
Facilitator: Do we all agree with this? All students: All agreed.			
Individual responses:	Student 8: question 6(b) is very simple, concentration (<i>c</i>), amount of substance (<i>n</i>) and volume (<i>v</i>) are variables, and the equation is $c = \frac{n}{v}$		
Facilitator: Is there anyone struggling with this? All students: Yes it is simple we use it in most chemistry calculations.			
Facilitator: Let us go through the following questions then and group 2 will lead us and project their answers. 6(e) The mass fraction of A in a mixture of two substances A and B is 0.30. 6(g) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture.			
		Group 2 Results	

 $\text{e/ Substance A} \rightarrow \text{A}$ $\text{Substance B} \rightarrow \text{B}$ $\text{mass fraction of A} = m_A$ $\text{Mixture of two substance} = \text{A} + \text{B}$ $m_A = \frac{\text{A}}{\text{A} + \text{B}} = 0.30$					
Group's discussions: 6(e)	Group 2; Student 5: First we have identified the variable quantities, as shown here (<i>pointing at the paper</i>). And the equation is as shown.	Group 1; Student 1: I have a problem, are these substances not supposed to be represented in terms of masses, like mass of substance A = m_A and do the same for substance B, like you taught us Mam?	Group 2; Student 2: Do you suggest that we change the way we wrote variables?	Group 1; Student 1: Yes because it says mass fraction, meaning at least use the symbol (m) to represent mass unlike writing A + B. because we can't tell if you are indicating masses or not?	Group 3; Student 2: Mam that's where we did not agree with our group, some are saying it is A + B and some says it is A x B.
Facilitator: Any volunteer to give a way forward. Group 3; Student 1: A fraction is part over a whole (<i>showing on the board</i>), referring also to their (<i>recommended</i>) text book, the total mass cannot be multiplied, it must be added, for example if you calculate molar mass of a compound NaOH, you add mass of Na+ O and H, not multiplying them. Facilitator: So how must we write this?					
Group's responses	Group 1; Student 5: (writing on the board), Mass fraction of substance A as	Group 1; Student 5: you know mam honestly teamwork it is important, but others dominate more and ended up	Groups 1, 3 and 4: Agreed that was correct.		

	$(m_{A(f)})$, mass of substance A as m_A, mass of substance B as m_B. Therefore the equation is; $m_{A(f)} = \frac{m_A}{m_A+m_B}$ $= 0.3$.	writing wrong results.	
Facilitator: Let's say you have an assignment as a group, where there is a misunderstanding, do research, and gather facts. Thereafter consult with senior students to assist you. Let us do 6(g).			
Group's responses	Group 2 Results: 6(g)  f, mass % A $\rightarrow$ %A mass % B $\rightarrow$ %B mass % C $\rightarrow$ %C mixture of three substance $\rightarrow$ A + B + C $\frac{A}{A+B+C} \times 100\% = \%A$ The problem is, you can identify variables but it can be difficult to formulate equations		
Facilitator: Is this right equation?			
Group's responses	Group 2; Student 4: Percentage is a fraction multiplied by hundred, this question is similar to the one above, except that we need to add substance C.	Group 3; Student 1: Let me do it, mass percentage of substance A is ($\% m_A$), mass of substance A as m_A, mass of substance B as m_B mass of substance C as m_C. Therefore the equation is; $\% m_A = \frac{m_A}{m_A+m_B+m_C} \times 100$.	

Facilitator: I hope we all understand what the question required; to first identify variable quantities and thereafter write the correct equation. Remember assigning the symbol to a variable is important, like in the question above m_C represents mass of substance C, unlike writing C which does not show another person if that is a symbol to represent the mass of a substance.

All Groups: Agreed that it is ok.

Question 7

For each of the words/phrases given below, state its meaning in column 2 and the “opposite” word in column 3.

Facilitator: Group 3 will lead us on this one.

Group 3 Results

QUESTION 7

Word/phrase	Meaning of Word	opposite word
Constant quantity	it is a quantity that does not change	
Absorption of heat	movement of heat	releasing of heat
Proton donor	a proton that donates its electrons	proton acceptor
Negative charge	having lower electric potential.	positive charge
Theoretical statement		
Product of a reaction	formation of product from reactants.	reactants of reaction
Exothermic reaction	heat is given off to the surroundings.	endothermic reaction
Reversible reaction	chemical reaction that results in equilibrium mixture of reactants and products	irreversible reaction
Oxidation.	losing of electrons.	reduction.

Group 3's discussion:	Group 3; Student 2: These are our answers for question 7, but we failed to answer the theoretical statement.	Group 3; Student 1: First word “constant” doesn’t change, and the opposite meaning I don’t know it.	Group 3; Student 5: I said the opposite word is a variable quantity but as a group we did not agree. Some students are not cooperative Mam.	
Facilitator: Why you did not agree? Group 3; Student 5: Mam you said we must recall and apply knowledge. Question 1 has the answers for both words constant and variable. When something is constant it means it doesn’t change. Then when it changes it is a variable which is the opposite word.				
Facilitator: Is this ok and everyone fine? All groups: Agreed.				
Group’s responses	Group 3; Student 4: Absorption of heat! Mam we didn’t agree on this one, I think to absorb is to take in, so here heat is taken in.	Group 3; Student 2: Sometimes one person takes all the decisions.	Group 3; Student 4: It is true Mam this word absorbs is very simple. Suppose for example I spilled off the water on the carpet, the carpet will be wet because it has absorbed that water. Also a sponge can absorb.	Group 2; Student 1: The opposite is release of heat.
Facilitator: Always in a group, use teamwork, you are connected to Wi-Fi, why didn’t you use an online dictionary? Remember in group work everyone must be happy about the answer, in cases like this you need to stand and defend your conclusion. Remember a group work mark is for the entire group, not for an individual. Facilitator: How about emission of heat?				
	Group 2; Student 5: Yes Mam it is still ok, because in question 1 the matching phrase is release of something, we can also say emission of heat.			
Facilitator: Group 4: What is the meaning of the theoretical statement and its opposite phrase? Remember question 4.				
Group’s responses	Group 4; Student 4: Theory refers to a set of fundamental non-observable entities and processes and makes testable predictions (<i>SAGE research methods online</i>).		Group 2; Student 2: It is a general statement that characterizes the nature of an entity or system in terms of non-observables, e.g. Chemistry: an acid donates protons in an acid-base reaction, (<i>University of ALBERTA online page</i>).	

Facilitator: In both group’s description we have the word “non-observable” what does it mean?		
Group’s responses	Group 1; Student 3: It’s obvious it something that we cannot see physically.	Group 3; Student 5: it means that in a theoretical description, it is something we know in our minds about acid-base reactions.
Facilitator: If everyone is ok, then what will be the opposite of this word “non-observable”		
Group’s responses	Group 1; Student 4: It is now “observable” Mam.	Group 2; Student 1: I am slightly confused, about non-observable and observable terms Mam.
Facilitator: Who can clarify this for us?		
Group’s responses	Group 3; Student 5: Let me say an acid like HCl dissociates to give H^{+} and Cl^{-} we cannot see the ions in the solution but we know in our mind that they are there. But for observable part it means we need to experiment this to check if the ions are there.	
Facilitator: I hope you all now clear about this, and also it is important to have your chemistry vocabulary book. Theoretical statements deal with theories, in your spare time check the Lewis Theory on acid-base dissociations.		

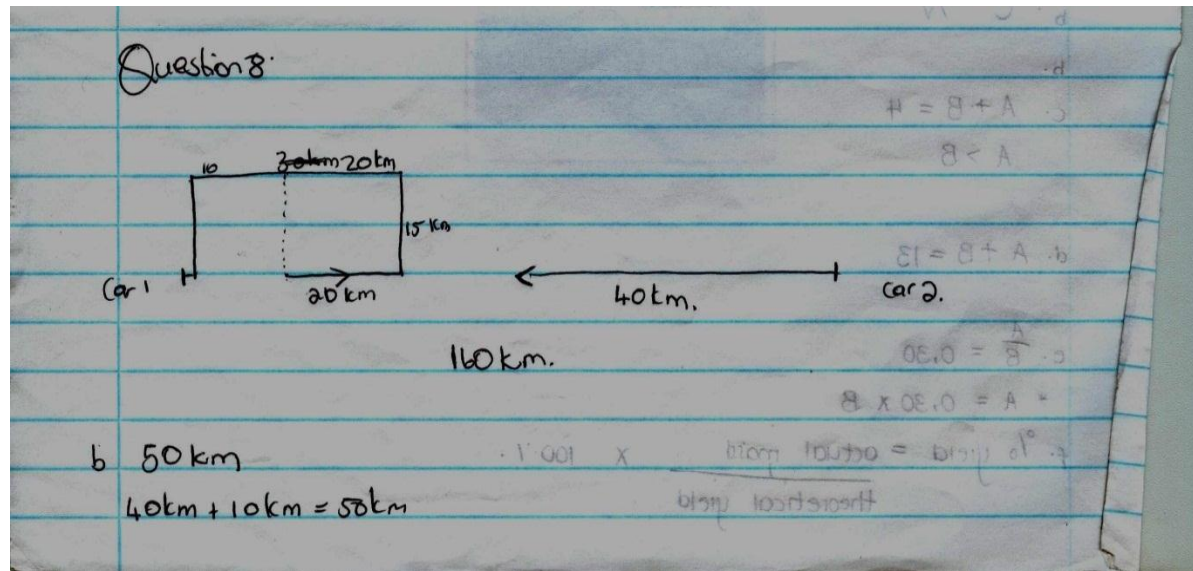
Question 8

Two cars, 160 km apart on a main road, travel towards each other. The first car travels for 20km and takes a right turn and travels for 15 km. It then turns left and travels for another 30km, and then turns left again and returns to the main road. In the meantime, the other car travels 40 km along the main road.

- Represent all the information given above as a diagram.
- What would be the distance between the two cars?

Facilitator: Group 1 can you take us through this question.
--

Group's results:



Group 2; Student 1: Mam left and right turn it was confusing?

Facilitator: Anyone with a way forward to assist in resolving the confusion?

Group 4; Student 1: Mam their diagram is not correct and also how they calculated the distance it is wrong. They cancelled 30 km, and only one arrow on the 20 km facing the main road. The arrows will help us to show the directions how these cars move. Let me project our group's diagram.

Group 4 results:

	(b) ∴ $160 \text{ km} - (20\text{km} + 30\text{km} + 40\text{km})$ Travelled on the main road $\quad\quad\quad 30\text{km}$ Travelled by car A car B $= 160\text{km} - 90\text{km}$ $= 70\text{km}$	
Group's responses	Group 4; Student 3: In this diagram, in number (b) we used distance travelled on the main road not those that involved turning left and right.	Group 2; Student 1: Mam during our group's discussion we disagreed when one group member said the word collision.
Facilitator: What is collision and which part of the question is asking about it?		
Group's responses	Group 3; Student 2: Mam the statement said two cars travel towards each other, were they not colliding?	Group 4; Student 4: The word "towards" is not referring to collision but simply means facing each other.
Facilitator: Remember it is very important to understand the whole phrase before answering the question. All groups: satisfied about the group 4 answers.		

Question 11

Three men need ten hours to tile the floor of a house.

(a). Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer)

(i) Men and floor of the house;

(ii) Three men and ten hours;

(iii) Number of tiles and surface area of the floor;

(iv) Number of men and time.

(b). Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct)

(i) Directly proportional;

(ii) Exponential;

(iii) Quantitative;

(iv) Inversely proportional;

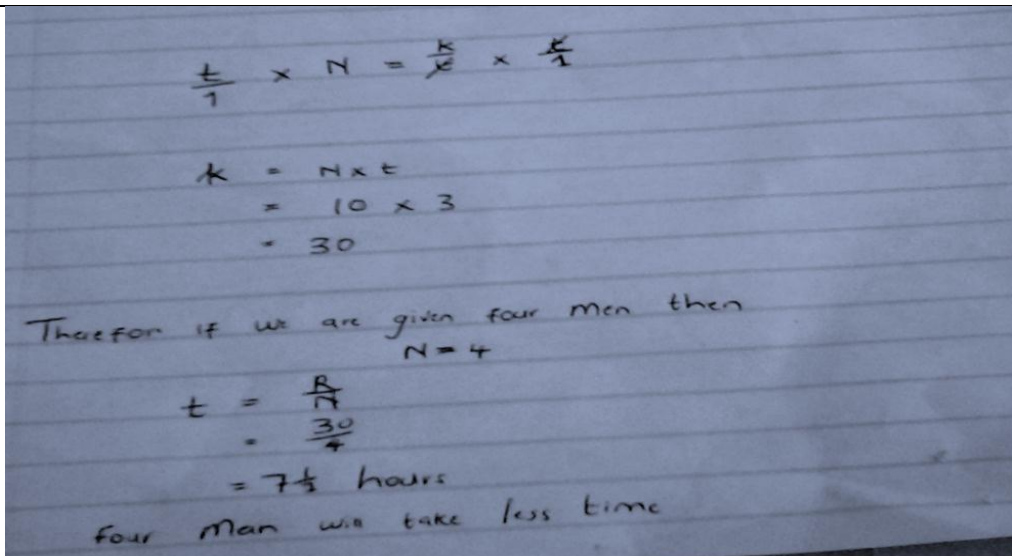
(v) Qualitative.

(c). Write an equation that relates the time (t) needed and the number of men (N) employed, where k is a constant.

(d). Will 4 men need more or less time, than 3 men to tile the floor of the house? (*Show how you reached your conclusion*).

Facilitator: Do you still remember the physical quantities? All groups: Yes. Facilitator: Any volunteer?			
Group 3; Student 1: a (i), b (i) and (iii), c is $N = k t$, d will require less time.			
Facilitator: Let us discuss group 3 results.			
Group's responses	Group 1; Student 2: Mam I believe that physical quantities are the one stated in the statement, which are three men and ten hours.	Group 2; Student 4: We agree with group 1, but in addition our equation is $N = \frac{k}{t}$ (indicating on the board).	Group 4; Student 4: Mam in our group we said a (iv) and the rest are similar.
Facilitator: Let us go stepwise, number (a) which group gave the correct answer?			
Group 3; Student 5: It is group 4 that “number of men and time”.			

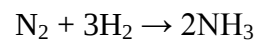
Facilitator: Are you clear with the answer given?			
Group’s responses	Group 2; Student 4: No what about the floor of the house?	Group 3; Student 2: We cannot include the floor of the house because we are not given it size, it is not quantified.	Group 2; Student 3: So we must choose those with given values.
Facilitator: Remember the word “quantity” involves units. Also in this example, the floor is constant, meaning that it doesn’t change and it cannot be regarded as one of the variable quantities. Can we move to number (b) if everyone is ok with (a). Also refer back to question 6.			
	Group 3; Student 5: Our answers are directly proportional and quantitative. Because we believe that number of men is directly proportional to time.		
Facilitator: What do you mean when you say something is directly proportional? Can we answer question (b) linking it with question (d). Will more men need more or less time to tile the floor of the house?			
	Group 1: Mam obvious more men will use less time.		
Facilitator: Ok, let us answer (a) then. The relationship between men and time is it directly proportional?			
Group’s responses	Group 1; Student 5: Mam if I remember it says when one quantity increases/decreases the other quantity increases/decrease with the same proportion.	Group 2; Student 5: This is our problem, what is directly proportional?	Group 4; Student 1: Therefore when more men are brought in they will take less time to tile the floor. This means when the other variable is increasing the other variable is also decreasing, so they are inversely proportional. Check example 6 (a).
Facilitator: I hope you all understand this. Is there anyone seeking clarity?			
	Group 1; Student 3: Honestly Mam to be part of the small group is better, as we can express our opinions, but others want to be dominant.		
Facilitator: That is true and it is advisable to form small study groups, express your own ideas and don’t just agree to write wrong results. Then let us do number (c). Group 2 lead us.			
	Group 2; Student 1: The equation we used above shows the inverse relationship between men and time, it is $N = \frac{k}{t}$.		
Facilitator: Can we use this equation to do number (d)?			
Group’s discussion	Group 4; Student 2: How?	Group 3; Student 5: Mam we must calculate the value of k, as it is not given? The calculation is as follows; (<i>projecting under document-camera</i>).	

		 $\frac{t}{N} \times N = \frac{k}{N} \times \frac{t}{N}$ $k = N \times t$ $= 10 \times 3$ $= 30$ Therefore if we are given four men then $N = 4$ $t = \frac{k}{N}$ $= \frac{30}{4}$ $= 7\frac{1}{2} \text{ hours}$ four men will take less time
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Facilitator: It is very important to understand what the question requires, application of knowledge. It is not good to answer 4(d) by just saying four men will require less time without showing how you reached that conclusion. It is important to use equations to solve verbal statements.

Question 22

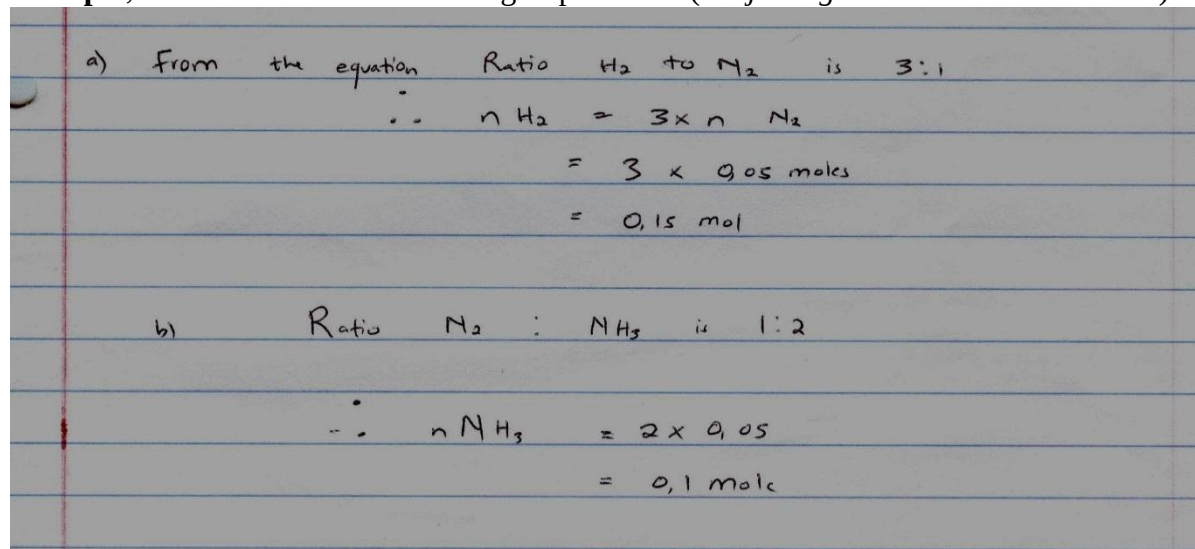
Consider the following reaction, and answer the questions which follow.



- (a) How many moles of hydrogen are necessary to react completely with 0.05 moles of nitrogen?
- (b) How moles of ammonia are produced?

Facilitator: Let us solve the problem, any volunteer?

Group 4; Student 2: Mam this is our group answer. (Projecting on the document camera).



Facilitator: Do you all understand how group 4 did this?

Group's responses

Group 1; Student 2: Mam sometimes the problem comes when you don't understand the use of moles and this ratio.

Group 3; Student 4: Mam we covered these sections but honestly some of us learn for the tests and exams, is there anything that can be done to assist us to keep this in our minds?

Group 4; Student 2: The most important thing is to check if the equation is balanced, thereafter calculate the moles of the other substances using the ratio.

Facilitator: It is true that you have to balance the equation first, and use the ratios to determine the moles of each substance. It is important to use step by step calculations to solve verbal statements. Honestly the way to keep things in mind is by practice and application of knowledge. Do lots of activities and when new topics are introduced try to link them to the previous topic learnt

Facilitator: Are you all clear?

Group 1; Student 5: Sometimes we fail simple things due to lack of understanding

All Groups: Agreed that they are fine.

Facilitator: Remember learning is a process. Thank you very much for your contributions and I hope you will use what we did to improve your study skills.

5.3. General findings:

The researcher used the constructivist approach for the intervention which supports the collaboration among students, with the guidance from the facilitator. The main focus was on the language and verbal reasoning skills which were identified by rectifying students' difficulties in pre-test and by the analysis of student-student interactions.

In the intervention program, the semantic memory testing strategy was used. This gives each group a task of online searching, compiling a vocabulary list of words they did not understand and then applying information and skills to answer questions.

The researcher started with question 1, which tested the understanding of words used both in everyday language and in scientific contexts. Although students' performance in the pre-test was satisfactory (about 75% gave correct answers). The facilitator wanted to clarify the difference between the words "non-technical" and "technical".

Question 2, tested students' ability to differentiate between descriptive and explanatory statements. The facilitator asked the student groups to search and find the answer to some parts of questions. Students' must be assisted in using their mind effectively like working in a group and accepting all ideas from other members.

In distinguishing quantitative and qualitative statements, the word "heavier" in the statement "a liter of water is heavier than that of ethanol", caused difficulties in the pre-test and SSI. The facilitator used a simple experiment involving touch to teach students: they were given two beakers containing different liquids and had to carry and feel them to find which beaker weighs more, and then weigh the beakers to confirm. The facilitator also asked students to indicate which activity was quantitative and which are qualitative. This showed that students struggled in terms of understanding the use of the word "heavier" in sentences.

In question 4, students were given activities: in the first activity students were required to inflate two balloons and thereafter pinch one of the balloons. In the second activity students were asked to balance an acid-base reaction equation. This was to stimulate their curiosity and increase understanding, to enable them to differentiate between the words fact, law, opinion, definition and theoretical statement. The results showed that some students were confused especially on the word “theoretical statement” and “fact”, but through groups’ analysis and exchange of information they were able to understand.

In question 5, students were required to identify the wrongly placed word within a phrase. This question caused difficulties in both the pre-test and SSI interactions. Also, in this question, students had difficulty in working collaboratively: some members indicated that they disagreed with the final conclusion of the group. The word “percentage” was confused with the word “amount”.

Question 6, required students to identify variable quantities and write equations. Many students were confused with the word “variable”. The facilitator asked students to share ideas and also to reflect on the meaning of the word. Sometimes students’ alternative conceptions can hinder their progress and performance in chemistry, as mentioned by Tytler (2002).

Question 7, required students to give the meanings and state the opposite words for some words/phrases. Students referred to question 4 to clarify to each other, and gave the meanings of the words, although some were still lagging behind.

Question 8, required students’ to draw a diagram to represent the information given in a verbal statement. The question seemed to confuse most students. Some students were able to clarify to other groups.

Question 11, tested the understanding of two words “inversely proportional” and “directly proportional”. This caused difficulty to some students.

5.4 Conclusions from the FSI

At the beginning, some students were reserved and felt that they were taken out of their comfort zone, especially when they had to personally discuss their answers. As the sessions moved on, some of these students were able to open-up and express views. Some students wanted to be dominant. Students also stated that it assisted them to do things together as a group since it would enable them to assist each other to clarify things.

The facilitator observed that semantic memory strategies can play a vital role in students’ learning, in terms of making concepts clearer. Guidance can be given on how to compile information and apply it, and this can result in students’ ability to hold information in the long-term memory. For example, questions 6 and 11 involved understanding of variable quantities. Although some of them did not at first grasp the meaning of the word in question 1, they were able to refer to this question when answering the other questions.

Episodic memory is related to the location and circumstances (Sprenger, 2008). During the intervention process, the students were given hands-on activities regarding qualitative and quantitative statements, in order to improve their understanding. This would also assist them to recall what they did and make connections when faced with new material that have the words “quantitative and qualitative”.

In the FSI program, students did simple experimental activities, had group discussions and made vocabulary note books to assist in triggering their ability to recall information. It is important to have a learning environment that encourages students to develop skills in storing information in long term memory. Active monitoring and assistance of students’ learning can

improve their cognitive processes enable to learn how their brains work best in storing information. Through the IP it became more apparent of what has to be done to improve cognitive abilities of students. A good learning environment has to be provided during classes and tutorials. The kinesthetic model showed that if students are instructed in the style that fits them, their critical thinking abilities will improve and they will use higher level thinking skills (Sprenger, 2008). How students reflect and connect and how they apply their existing knowledge to the new knowledge will also improve.

The information processing theory was also used as one of the guiding theories for this research. It describes long term memory that comprises of implicit and explicit memory. One of the students asked, during the intervention, if the system can teach them how to store knowledge in memory rather than just studying for the examinations and tests, after which everything “seem to be vapourised”. This question shows that students lack some skills on information processing and application of knowledge to improve their cognitive abilities.

The author’s observation in this study is that traditional lecture halls limit some of the activities which would assist in students’ better understanding and application of knowledge. It would be much better if students can sit and listen in large venues, which would not restrict free movement and small group discussions of the instructor and students. In the small group settings, during the IP, students were able to express themselves in their own home language (Setswana, Isizulu or English) all of which the facilitator understood.

The extended four year BSc program is a special programme. Students needs to be given a solid foundation so that they can progress to higher levels of learning. If the settings in this program can be changed to use smaller groups, than the traditional method used in the mainstream courses, students would perform better. The small group settings also assisted the lecturer in identifying which students were struggling to cope and helped to overcome their

difficulties. Students also turned to classmates to help them develop a better understanding during the intervention, which can also be beneficial.

CHAPTER 6

POST TEST RESULTS AND ANALYSIS

6.1 Introduction

This chapter mainly discusses students' performance in the post-test. It then compares students' performance in the pre-test and post-test and also the groups of students who had the instruction (experimental) program and those that did not (control).

The post-test was given in July 2015 for both groups (2013 and 2014 students). 79 students participated in the post-test as compared with 170 students who participated in the pre-test. This was because many students dropped out of the programme: the ethics rules required students to participate voluntarily. The test was administered by the technicians in the chemistry department, who volunteered their services. This was to remove any possibility of ethical problems because the researcher was also the students' lecturer. The question paper was answered by 79 students; 40 students (21 from 2013 and 19 from 2014) were the control group and 39 students (18 from 2013 and 21 from 2014) were the experimental group.

6.2 Post-Test Memorandum, Results and Discussions

The post-test had 7 questions and the pre-test had 24 questions. The reason fewer questions were used in the post-test was because some skills were tested twice in the pre-test to check students' consistency in answering the questions (reliability and validity). The other reason was to avoid students' tiredness as the test was given after hours (17H00) when the majority of the students had come from their academic afternoon sessions.

The memorandum for the post test will be given first: the main objectives of each question are first stated and their solutions.

6.2.1 Question 1

This question is analogous to question 1 of the pre-test. See Appendix B (pages 263-273) for the question.

6.2.1.1 Objective of question 1:

This question tests understanding of some non-technical words/phrases often used in chemistry. Lack of understanding of these words/ phrases will hinder learning and understanding of chemistry. It involves matching words/ phrases in column A with words/ phrases in column B. The correct solutions are as shown in table 6.1 and students' performance is shown in table 6.2.

6.2.1.2 Solution of question1:

Table 6. 1: Solutions to all parts of question 1

Column A (Words/Phrases)	Column B (Phrases/Statements)
1. Boiling point	h. The temperature at which the vapour pressure of the liquid equals the atmospheric pressure.
2. Co-efficient	i. Numbers in front of formulas in chemical equations.
3. Concentrated solution	m. A solution that has a large ratio of the amount of solute to the solvent.
4. Decomposition	l. A chemical reaction that changes one substance into two or more simpler substances.
5. Dependent variable	b. The experimental variable of a pair of variables whose value is determined by the other variable (independent).
6. Effusion	j. Movement of gas through a very tiny opening into a

	region of lower pressure.
7. Experimental Data	k. The information obtained in an experiment often in the form of physical quantities.
8. Indicator	d. A chemical substance put in a solution being titrated and whose change in colour signals the end point.
9. Mass fraction	e. The ratio of the mass of one component of a mixture to the total mass of that mixture.
10. Percentage yield	c. The ratio of the amount of product obtained in the laboratory experiment to the theoretical yield multiplied by hundred.
11. Product of reaction	g. End results of a chemical reaction.
12. Qualitative analysis	a. The use of experimental procedures to determine what elements are present in a substance.
13. Standard solution	f. Any solution whose concentration is accurately known

6.2.2 Question 2

This question is analogous to questions 2, 3 and 4 of the pre-test.

Consider each statement given below and state whether it is best considered to be an experimental **law**, a **definition**, a **quantitative observation**, a **descriptive statement** or an **explanatory statement**.

- (a) Noble gases are unreactive because their outermost valence shell is full. It can therefore neither gain nor lose electrons.
- (b) Matter consists of tiny particles called atoms.
- (c) Compounds are formed from two or more different elements which are always combined in the same fixed proportion by mass.
- (d) In a chemical reaction, the atoms re-arrange but they do not break apart.

- (e) A sample containing sulphur and carbon is completely burned in air, and produced 0.64g of CO_2 and 0.22g of SO_2 .

6.2.2.1 Objective of question 2

This question tests the ability to differentiate between descriptive statements, explanatory statements, laws, definitions and quantitative statements.

6.2.2.2 Solutions of question 3

- a. **Answer:** *Explanatory statement.*
- b. **Answer:** *Descriptive statement.*
- c. **Answer:** *Explanatory statement.*
- d. **Answer:** *Explanatory statement.*
- e. **Answer:** *Quantitative observation.*

6.2.3 Question 3

This question was analogous to question 6 of the pre-test and individual students' performances will be discussed.

This question had two parts i.e., 3(a) in which students convert quantitative statements into equations, and 3(b) use the equations given in 3(a) to do calculations. Given the following statements, convert them into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statements (a).

- (a) Density is defined as the ratio of an object mass to its volume.

- (b) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture.
- (c) Concentration is defined as the number of moles of a substance divided by the volume of that substance.

6.2.3.1 Objective of question 3(a)

This question tests the ability to convert quantitative statements into equations. Students must first identify all the variable quantities in the statements and give symbols to them. A hint was given to students for statement (a) to assist students on what is expected from them.

6.2.3.2 Solutions of question 3(a)

- a. **Answer:** $\rho = \frac{m}{V}$; Variable quantities are density (ρ), m (mass) and volume (v).
- b. **Answer:** $m_A\% = \frac{m_A}{m_A+m_B+m_C} \times 100$; $m_A\%$ = mass percent of a substance A, m_A = mass of A, m_B = mass of B, m_C = mass of C.
- c. **Answer:** $c_A = \frac{n_A}{V}$; c_A = concentration of A, n_A = amount of A and v = volume of solution.

6.2.3.3 Objective of question 3(b)

This question tested the ability to use equations to do calculations from given verbal statements.

- (a) The density of 8.20ml vinegar contained in a test tube. The empty test tube had a mass of 9.2 g and after filling it with vinegar the mass was 20.2g.
- (b) The mass percentage of substance A, given that the masses of substances A=8 g, B=20g and C=26g.

(c) The concentration of 0.25mol HCl contained in a 250 ml volumetric flask.

6.2.3.3 Solutions of question 3(b)

a. **Answer:**

Mass of vinegar = (mass of test tube + vinegar)-mass of empty test tube.

$$= 20.2\text{g} - 9.2\text{g} = 11\text{g}$$

$$\rho = \frac{m}{v} = \frac{11\text{g}}{8.2\text{ml}} = 1.34\text{ g/ml}$$

b. **Answer:** $m_A\% = \frac{m_A}{m_A + m_B + m_C} \times 100$

$$m_A\% = \frac{8\text{g}}{8\text{g} + 20\text{g} + 26\text{g}} \times 100$$

$$m_A\% = \frac{8\text{g}}{54\text{g}} \times 100 = 0.148 \times 100 = 14.8\%$$

d. **Answer:** $c_A = \frac{n_A}{V}$

$$v = \frac{250}{1000} = 0.25\text{ dm}^3$$

$$c_A = \frac{0.25\text{ mol}}{0.25\text{ dm}^3} = 1.0\text{ mol.dm}^{-3}$$

OR

$$c_A = \frac{n_A}{V}, \text{ given; } v = 250\text{ ml}$$

$$c_A = \frac{0.25\text{ mol}}{250\text{ ml}} = 0.001\text{ mol.ml}$$

6.2.4 Question 4

This question is analogous to question 11 of the pre-test.

Four cleaners took forty minutes to clean the floor of the laboratory.

(a). Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer).

- (i) Cleaners and floor of the laboratory; (ii) Four Cleaners and forty minutes;
 (iii) Forty minutes and surface area of the floor; (iv) Number of cleaners and time.

(b). Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct)

- (i) Directly proportional; (ii) Exponential;
 (iii) Quantitative; (iv) Inversely proportional;
 (v) Qualitative.

(c). Write an equation that relates the time (t) needed and the number of cleaners (N) employed, where k is a constant.

(d). Will 6 cleaners need more or less time, than 4 cleaners to tile the floor of the house?

6.2.4.1 Objective of question 4

This question tested students understanding of various important aspects of inverse proportion reasoning.

6.2.4.2 Solutions of question 4

(a). (iv).

(b). (iii) and (iv).

(c). **Answer** = $N_{men} = \frac{k}{t}$

(d). **Answer:** $N_{\text{men}} = \frac{k}{t}$

$$\therefore k = N \times t = 4 \times 40 = 160$$

$$t = \frac{k}{N(\text{men})} = \frac{160}{6} = 26.7 \text{ minutes. More cleaners will use less time.}$$

6.2.5 Question 5

This question is analogous to question 8 of the pre-test.

Three students, Katlego, Lesego and Bonolo, stay in three different residences, A, B and C on a straight road. Katlego stays in residence A which is 2.4 km away from residence C where Lesego is staying. On a daily basis Katlego travels 600 metres from her residence to the fetch Bonolo who stays in residence B which is between A and C, to attend classes.

- (a) What is the distance between Bonolo and Lesego's residences?
- (b) Represent all information given above as a diagram.

6.2.5.1 Objective of question 5

This question tested whether students can use verbal information to do a simple calculation (part a) and to represent the verbal information in a form of a diagram (part b).

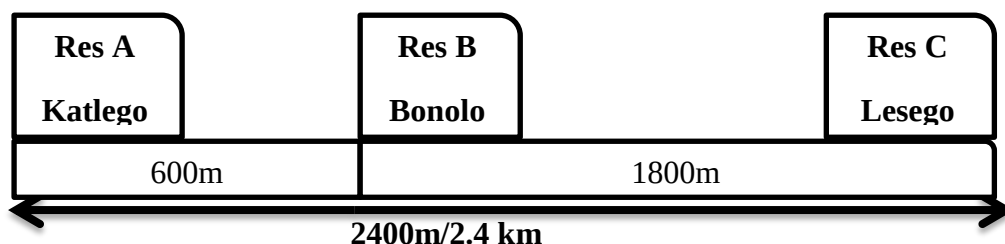
6.2.5.2 Solutions of question 5

- (a) **Answer:** 1km = 1000m

$$\text{Given } 2.4 \text{ km} = 2400 \text{ m}$$

$$\therefore \text{Distance} = 2400\text{m} - 600\text{m} = 1800\text{m} / 1.8 \text{ km}$$

- (b) Represent all information given above as a diagram



6.2.6 Question 6

This question is analogous to question 19 of the pre-test.

A student pipetted 10 ml of 1M sodium hydroxide (NaOH) solution into a beaker, and diluted it with 100 ml of distilled water. Consider the following statements and state whether they are correct or not.

- (a) Mass of NaOH in the solution will remain constant.
- (b) The volume of the solution will increase.
- (c) Mass of the solution will increase.
- (d) The concentration of NaOH in the solution will decrease.
- (e) The concentration of NaOH in the solution will increase.

6.2.6.1 Objective of question 6

This question tested the comprehension of some simple concepts that are important in chemistry.

6.2.6.2 Solutions of question 6

- a. **Answer:** *Correct.*
- b. **Answer:** *Correct.*
- c. **Answer:** *Correct.*

d. **Answer:** *Correct.*

e. **Answer:** *Incorrect.*

6.2.7 Question 7

This question is analogous to question 21 of the pre-test.

A student performed an acid-base titration in the laboratory and obtained the following results after adding 0.12 M NaOH into an acid.

	Trial 1	Trial 2	Trial 3
Initial volume	0.50ml	11.20 ml	22.20 ml
Final volume	11.10	22.00 ml	32.80 ml
Volume added			

(a) Calculate the average volume added.

(b) Calculate the number of moles of NaOH added.

6.2.7.1 Objective of question 7

This question tested whether students use the defining equation to solve a problem involving acid-base titrations.

6.2.7.2 Solution:

(a) **Answer:** $\frac{(10.6+10.8+10.6)ml}{3} = 10.7 \text{ ml}$

(b) **Answer:** $c = \frac{n}{v}$

$$\therefore n = c \times v$$

$$= 0.12 \text{ mol} \cdot \cancel{dm}^{-3} \times \frac{10.7}{1000} \cancel{dm}^3$$

$$= 0.0013 \text{ mol}$$

6.3 Summaries of students' performance in the pre-test and post-test.

The analogous questions and skills tested in the pre-test and post-test questions are summarized in table 6.2. The SPSS method was used to analyze the students' performances.

Students' performance for the two groups (control and experimental) of students are shown in tables 6.3 -6.4 and figures 6.1-6.2. Followed by the individual students' performance for both the control and experimental groups as shown in tables 6.5-6.8 and figures 6.3—6.6, for the pre-test and post-test. Followed by the comparisons of students' performance to the analogous questions tested in both the pre-test and post-test

Table 6. 2: Summary of the pre-test and post- test skills.

Questions		Skills tested
Post-test	Pre-test	
Question 1	Question 1	The understanding of some non-technical words/phrases which are often used in chemistry.
Question 2	Question 2, 3 and 4	The ability to differentiate between descriptive statements, explanatory statements, a law, a definition and a quantitative observation.
Question 3	Question 6	The ability to convert quantitative statements into equations and use these equation to do calculation from given verbal statements.
Question 4	Question 11	The understanding of various important aspects of inverse proportion reasoning.
Question 5	Question 8	The ability to use verbal information to do a simple calculation (part a) and to represent the verbal information in a form of a diagram (part b).
Question 6	Question 19	Comprehension of some simple concepts that are important in chemistry, by applying laws and equations.
Question 7	Question 21	The ability to use the defining equation/s to solve problems involving calculations.

Table 6 3: Pre-test Entire Groups Summary

Question	Groups (2013 + 2014)	N (frequency)	Mean (%)	Std. Deviation	Std. Error Mean	Chi's Square test (p-value)	Cramer's value (v-value)
Q1	Control	40	81	12.4117	1.9625	0.180	0.25
	Experimental	39	75	19.8704	3.1818		
Q2,3,4	Control	40	62	14.6040	2.3091	0.086	0.38
	Experimental	39	56	15.2548	2.4427		
Q6	Control	40	42	20.7210	3.2763	0.177	0.34
	Experimental	39	34	22.5028	3.6033		
Q8	Control	40	28	37.6548	5.9537	0.011	0.50
	Experimental	39	9	25.3185	4.0542		
Q11	Control	40	37	21.7470	3.4385	0.248	0.25
	Experimental	39	32	19.9451	3.1938		
Q19	Control	40	64	29.6507	4.6882	0.195	0.27
	Experimental	39	54	36.3857	5.8264		
Q21	Control	40	34	38.2091	6.0414	0.007	0.51
	Experimental	39	14	22.7940	3.6500		

Figure 6 1: Pre-Test Summaries

Table 6 4: Post-Test Entire Groups Summary

Questions	Groups (2013+ 2014)	N (frequency)	Mean (%)	Std. Deviation	Std. Error Mean	Chi's Square test (p-value)	Cramer's value (v-value)
Q1	Control	40	77	19.0877	3.0180	0.001	0.67
	Experimental	39	90	12.7830	2.0469		
Q2	Control	40	59	27.3205	4.3198	0.025	0.49
	Experimental	39	72	24.1565	3.8681		
Q3(a)	Control	40	63	28.2998	4.4746	0.009	0.56
	Experimental	39	79	24.0192	3.8462		
Q3(b)	Control	40	59	28.8736	4.5653	0.011	0.56
	Experimental	39	77	31.6930	5.0749		
Q4	Control	40	44	21.1890	3.3503	0.023	0.51
	Experimental	39	54	20.4932	3.2815		
Q5	Control	40	68	38.4808	6.0843	0.002	0.61
	Experimental	39	91	25.3185	4.0542		
Q6	Control	40	82	16.5715	2.6202	0.596	0.11
	Experimental	39	84	18.2796	2.9271		
Q7	Control	40	73	31.9254	5.0478	0.035	0.42
	Experimental	39	86	22.7940	3.6500		

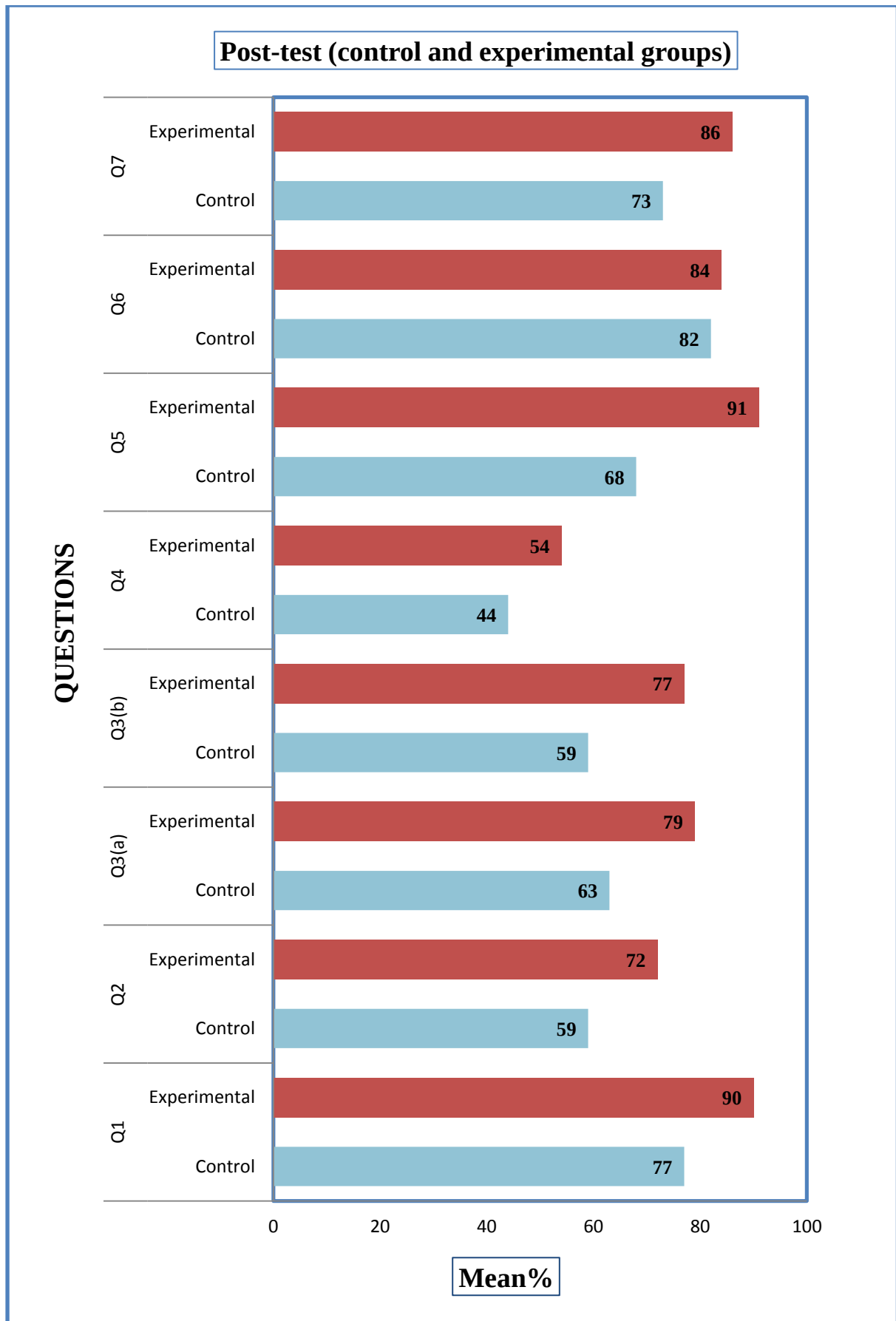


Figure 6 2: Post-Test Summaries

Table 6 5: 2013 Control (individual) Summaries.

Control	PRE-TEST							AVE	POST-TEST							AVE	
2013	Q1	Q2,3,4	Q6	Q8	Q11	Q19	Q21	AVE	Q1	Q2	Q3a	Q3b	Q4	Q5	Q6	Q7	AVE
student 1	83	42	11	0	25	60	50	39	46	40	50	67	40	100	100	50	62
student 6	94	38	28	0	50	80	0	41	85	40	50	33	60	100	60	100	66
student 7	89	52	61	100	25	100	100	75	100	80	75	67	20	100	100	0	68
student 11	94	54	28	0	25	60	50	44	7.7	60	75	100	60	0	100	100	63
student 12	78	60	39	0	50	0	0	32	46	20	50	67	40	100	100	100	65
student 15	89	48	39	0	0	80	0	37	62	80	25	0	100	100	100	100	71
student 19	78	65	33	0	25	40	0	34	62	100	50	33	60	100	80	100	73
student 21	56	75	33	0	50	80	0	42	77	100	50	67	20	100	80	100	74
student 23	78	59	39	0	25	60	0	37	77	20	100	33	40	100	60	100	66
student 33	56	58	33	0	50	60	0	37	54	40	0	67	60	0	100	50	46
student 36	67	40	22	50	25	20	0	32	69	100	50	67	20	100	100	100	76
student 39	89	58	22	100	25	100	50	63	100	40	50	33	0	100	80	100	63
student 43	78	79	44	0	50	0	0	36	69	40	75	67	40	50	80	50	59
student 49	78	73	11	0	25	20	0	30	85	40	50	67	40	100	80	0	58
student 51	100	42	33	0	50	60	0	41	62	60	25	33	40	50	80	50	50
student 52	78	29	33	0	0	20	50	30	100	60	75	67	20	50	60	50	60
student 55	50	53	22	0	25	40	0	27	85	80	25	33	80	50	100	50	63
student 60	94	86	39	0	0	20	0	34	85	40	100	33	40	50	60	100	64
student 62	89	68	33	0	50	20	0	37	62	60	50	100	60	50	80	100	70
student 64	100	75	22	0	25	40	100	52	62	100	100	67	40	50	60	50	66
student 70	83	70	33	50	25	40	0	43	85	20	50	100	40	50	100	50	62
AVERAGE	81	58	31	14	30	48	19	40	71	58	56	57	44	71	84	71	64

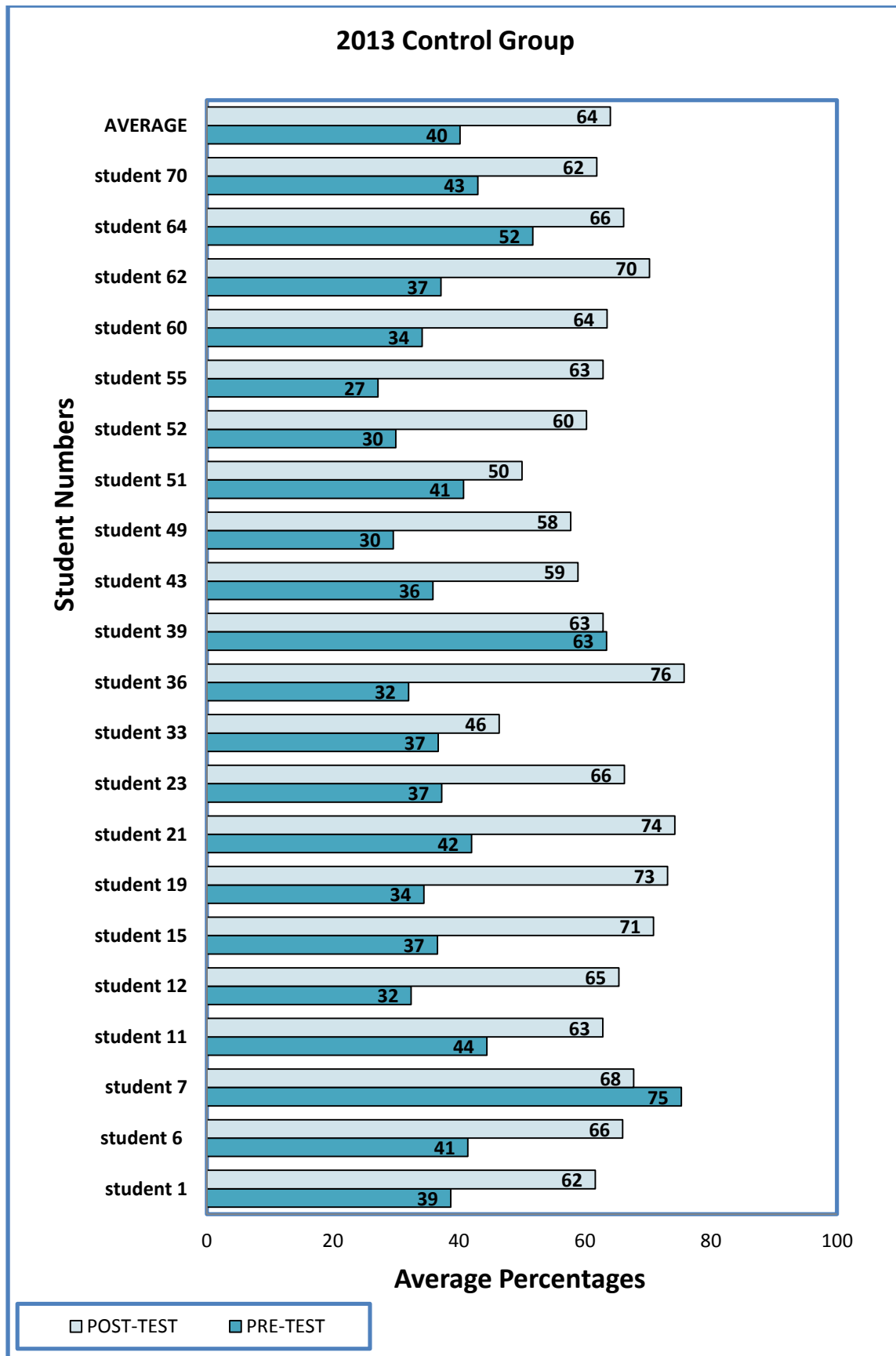


Figure 6 3: 2013 Control (individual) Performances

Table 6 6: 2014 Control (individual) Summaries

Control	PRE-TEST								POST-TEST								
2014	Q1	Q2,3,4	Q6	Q8	Q11	Q19	Q21	AVER	Q1	Q2	Q3a	Q3b	Q4	Q5	Q6	Q7	AVER
student 1	78	68	57	0	20	75	100	57	85	40	100	100	20	50	80	100	72
student 6	70	71	36	0	0	75	100	50	85	60	100	33	60	50	40	100	66
student 19	83	64	21	50	40	75	50	55	100	20	100	67	20	0	80	100	61
student 20	83	53	71	60	60	50	100	68	85	60	100	100	20	100	80	100	81
student 22	100	57	7	100	60	100	0	61	100	60	50	67	40	100	100	50	71
student 30	94	50	60	50	40	75	50	60	62	80	50	0	60	50	40	100	55
student 37	83	48	43	50	40	75	100	63	100	60	50	67	80	100	60	50	71
student 42	78	82	86	0	60	100	50	65	85	80	100	67	60	0	80	50	65
student 46	83	50	86	0	60	75	100	65	85	100	50	33	40	100	80	50	67
student 50	72	81	57	0	60	75	0	49	69	60	50	100	20	0	100	100	62
student 60	78	76	36	50	20	50	0	44	69	80	25	33	40	100	80	100	66
student 62	61	69	43	50	60	100	50	62	85	100	100	67	40	100	100	0	74
student 63	78	52	86	0	60	100	50	61	85	60	100	100	80	0	80	50	69
student 73	78	44	71	50	60	100	50	65	100	60	50	100	20	100	80	50	70
student 74	56	70	21	50	0	75	0	39	77	0	25	100	40	50	80	50	53
student 80	94	70	57	100	80	75	50	75	69	20	50	33	20	0	80	100	47
student 83	78	76	64	100	40	100	0	65	62	80	50	33	60	100	100	100	73
student 92	89	81	57	0	80	100	50	65	100	80	100	33	60	100	80	50	75
student 93	83	87	64	100	20	75	50	68	85	20	100	33	40	100	80	100	70
AVERAGE	80	66	54	43	45	82	50	60	84	59	71	61	43	63	79	74	67

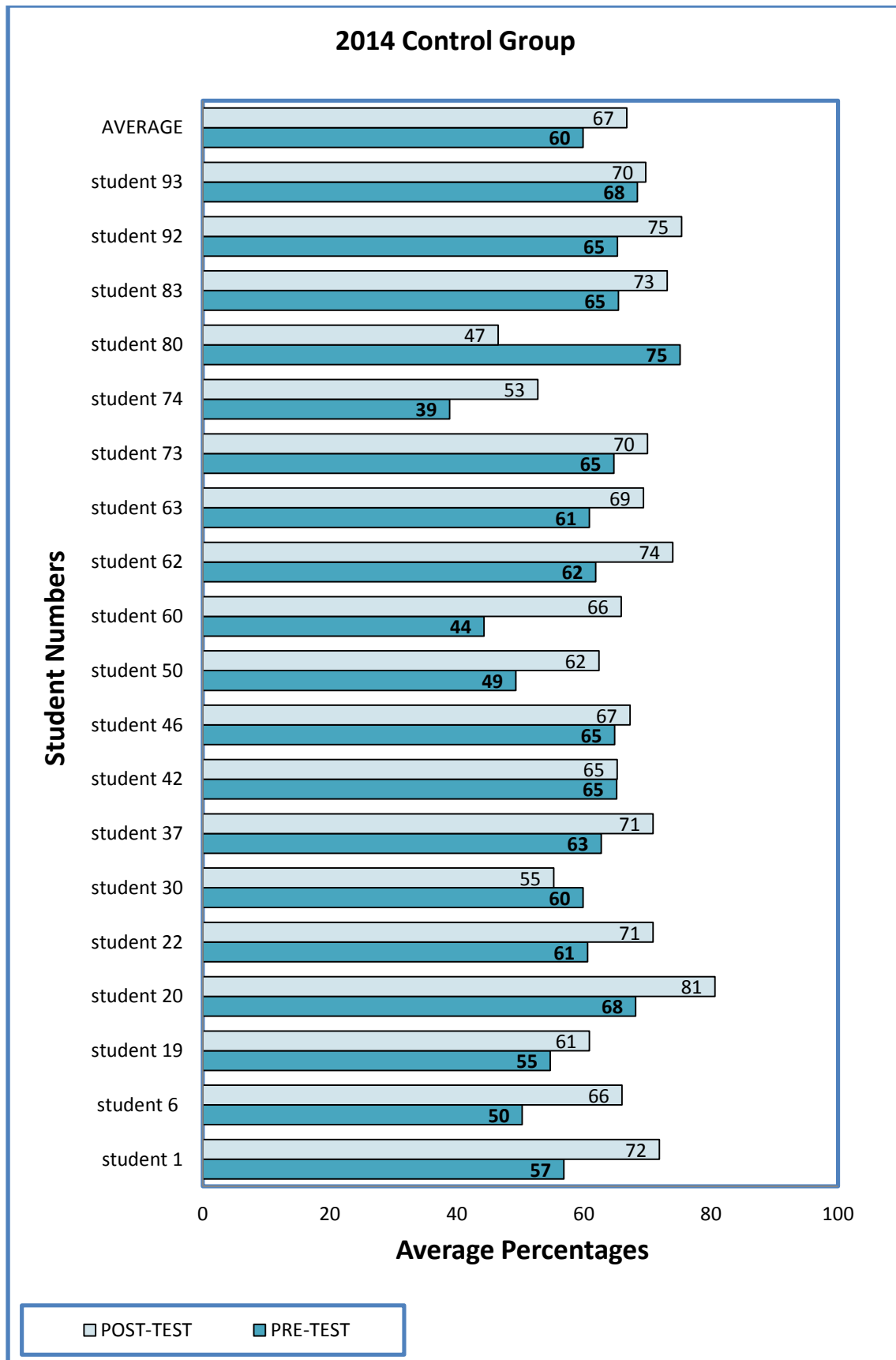


Figure 6 4: 2014 Control (individual) Performances

Table 6 7: 2013 Experimental (individual) Summaries

Experimental	PRE-TEST								POST-TEST								
2013	Q1	Q2,3,4	Q6	Q8	Q11	Q19	Q21	AVE	Q1	Q2	Q3a	Q3b	Q4	Q5	Q6	Q7	AVER
student 2	78	57	22	0	25	20	50	36	92	100	100	67	0	100	60	100	77
student 4	100	43	22	0	0	40	0	29	77	80	50	33	40	100	60	100	68
student 5	61	54	22	0	50	0	0	27	85	40	100	67	80	100	100	50	78
student 9	89	51	33	0	50	0	0	32	100	100	75	67	20	100	60	50	72
student 13	78	36	0	0	50	60	50	39	100	80	75	100	40	100	100	100	87
student 26	78	52	28	0	0	60	0	31	100	60	75	100	60	100	80	100	84
student 29	89	43	28	50	0	60	0	39	100	100	75	100	40	100	100	100	89
student 32	39	48	39	0	25	60	0	30	100	20	100	100	80	50	100	100	81
student 34	61	73	39	0	25	60	0	37	85	40	100	67	80	100	100	100	84
student 35	28	21	0	0	25	60	0	19	100	40	50	100	40	100	80	100	76
student 40	72	25	33	0	25	0	0	22	69	100	50	100	60	100	80	100	82
student 42	100	32	28	0	50	20	0	33	69	100	75	67	40	100	100	50	75
student 44	78	53	28	0	50	60	0	38	85	60	100	100	80	100	100	100	91
student 46	89	60	39	100	0	80	50	60	77	100	50	0	60	100	80	100	71
student 58	67	52	28	0	50	20	0	31	100	60	50	33	60	100	100	100	75
student 59	72	63	22	0	0	0	0	22	100	40	50	67	60	100	80	100	75
student 66	44	59	28	0	0	0	0	19	92	100	50	100	20	50	100	100	77
student 73	83	67	33	0	50	80	0	45	100	60	50	100	60	100	80	100	81
AVERAGE	73	49	26	8	26	38	8	33	91	71	71	76	51	94	87	92	79

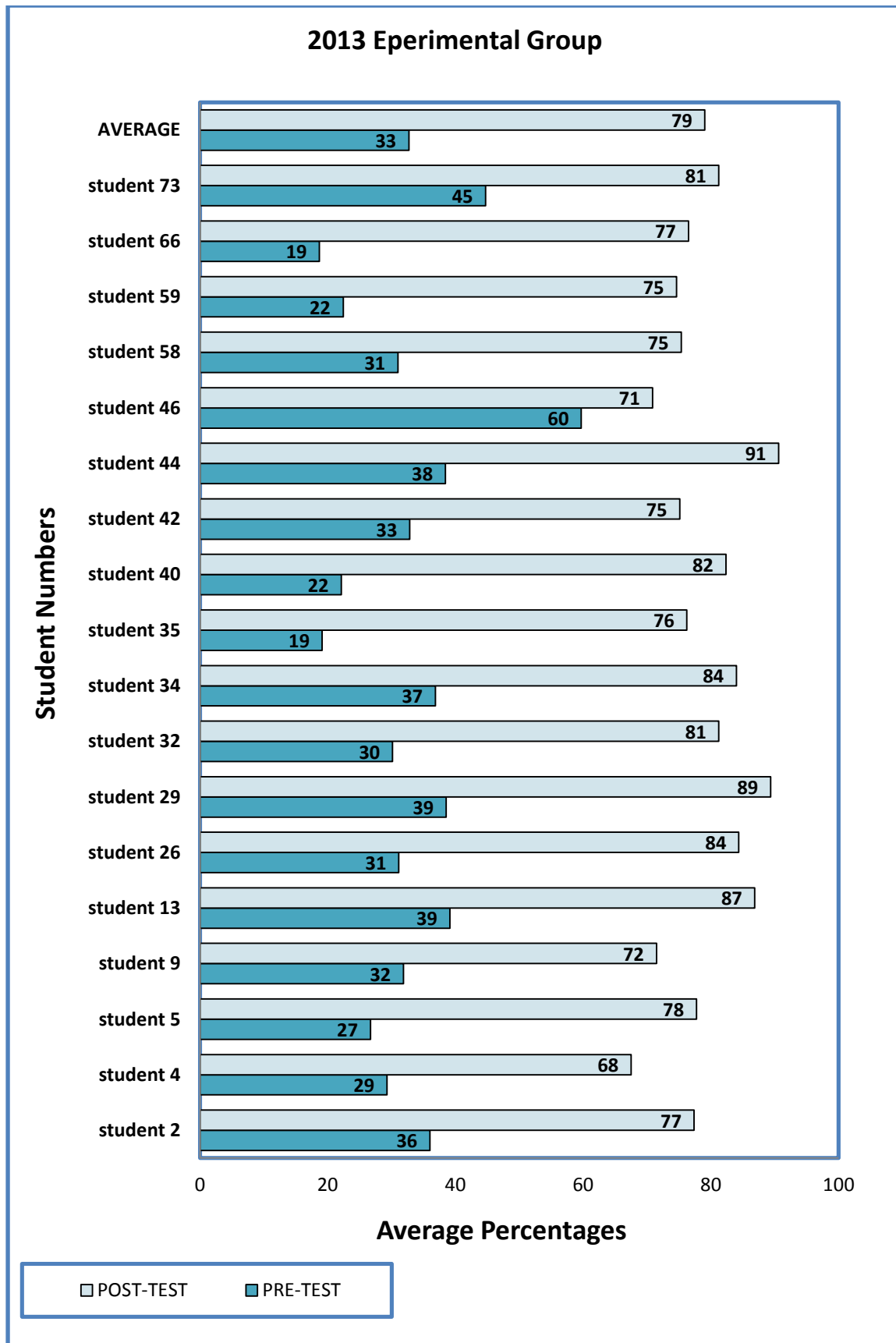


Figure 6 5: 2013 Experimental (individual) Performances

Table 6 8: 2014 Experimental (individual) Summaries

Experimental	PRE-TEST								POST-TEST								
2014	Q1	Q2,3,4	Q6	Q8	Q11	Q19	Q21	Ave	Q1	Q2	Q3a	Q3b	Q4	Q5	Q6	Q7	Ave
student 8	66	69	21	0	60	100	50	52	54	60	100	67	60	100	100	100	80
student 11	88	70	36	0	40	100	0	48	77	80	25	67	20	100	100	100	71
student 13	100	81	71	0	20	0	0	39	100	60	100	100	80	0	80	50	71
student 14	56	31	7	50	60	0	50	36	85	100	100	100	80	100	80	100	93
student 18	94	69	43	0	0	50	0	37	100	60	50	67	60	100	100	100	80
student 21	72	62	0	0	40	0	0	25	100	100	100	0	60	100	40	50	69
student 23	89	55	86	0	20	75	50	54	100	100	75	100	60	100	100	100	92
student 25	100	73	43	0	60	0	0	39	100	100	100	0	40	100	80	50	71
student 29	72	53	45	0	40	75	0	41	100	60	100	100	80	100	80	100	90
student 35	33	56	21	0	20	75	0	29	85	20	100	33	40	100	60	100	67
student 39	56	51	50	0	20	75	0	36	85	60	100	100	80	100	80	50	82
student 41	100	74	86	0	40	100	0	57	69	80	100	67	40	100	80	100	80
student 52	83	36	21	0	40	100	50	47	69	60	50	100	40	0	100	100	65
student 54	72	80	86	0	40	75	50	58	100	100	100	100	60	100	40	100	88
student 56	89	81	71	0	40	75	50	58	69	60	100	100	60	100	40	100	79
student 58	94	68	36	0	0	100	50	50	85	80	100	100	60	100	80	100	88
student 68	56	68	29	0	40	75	50	45	85	100	100	100	80	50	100	50	83
student 75	44	69	64	50	40	75	0	49	100	60	100	100	40	100	80	50	79
student 77	78	43	0	0	60	100	0	40	100	60	50	33	80	100	100	50	72
student 86	94	54	21	0	40	100	0	44	100	60	100	100	40	100	80	100	85
student 89	100	51	29	100	40	75	0	56	100	60	50	100	40	100	100	50	75
AVERAGE	78	62	41	10	36	68	19	45	89	72	86	78	57	88	81	81	79

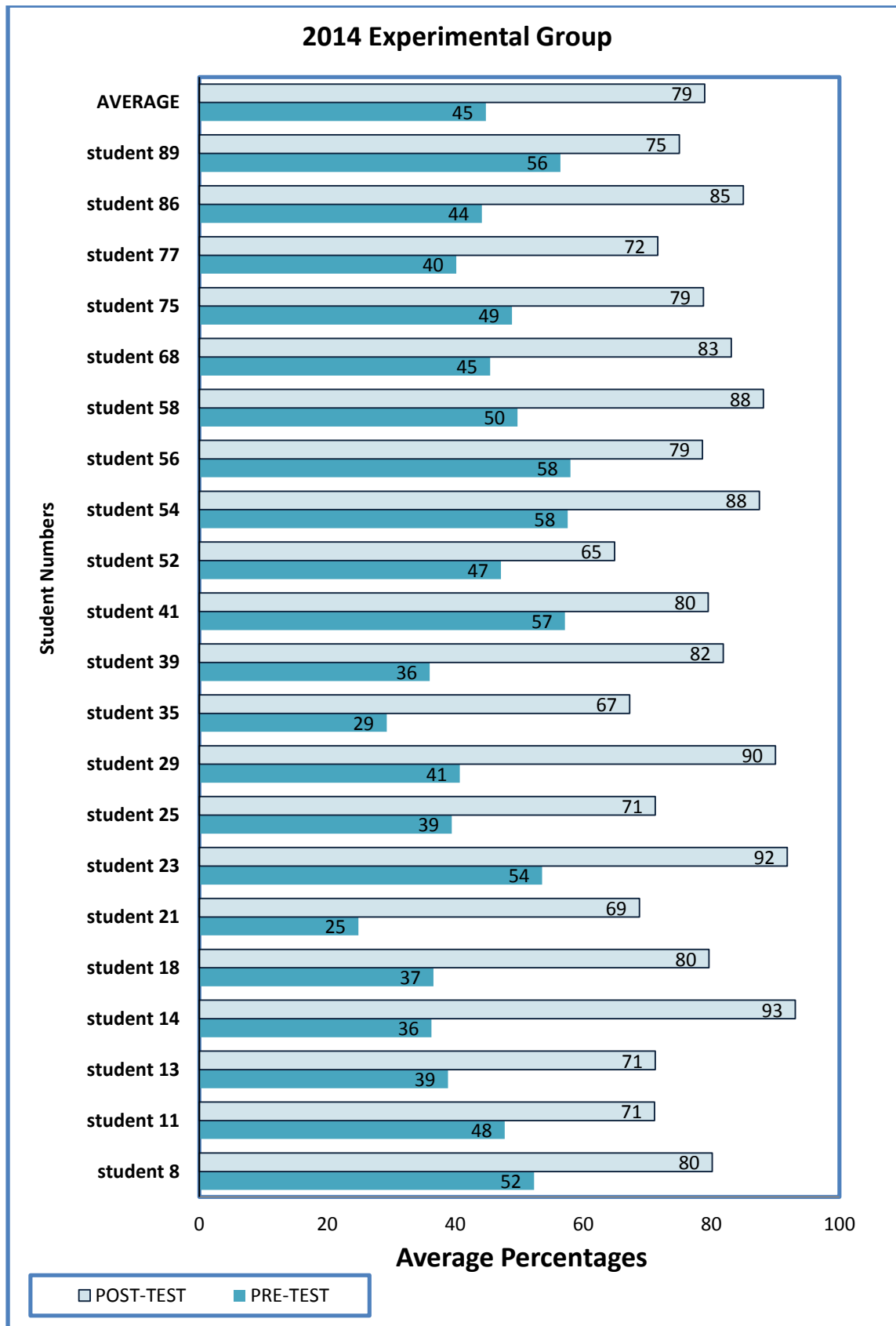


Figure 6 6: 2014 Experimental (individual) Performances

6.3.1 Comparison of students' performance in the post-test and pre-test

Students' performance in question 1 of the post-test was compared with their performance to question 1 in the pre-test, for the experimental and control groups.

In the pre-test, the percentages of students who gave correct answers were 75% for the experimental group and 80% for the control group of students. This percentage increased to 90% for the experimental group but slightly dropped to 77% for the control group in the post-test. The p-value in this question, was 0.001, indicated that there was a significant statistical difference in students' performance. The experimental group of students answered the question better than the control group of students.

Students' performance in question 2 of the post-test was compared to questions 2, 3 and 4 in the pre-test, for the experimental and control groups. In the pre-test, the percentages of students who gave correct answers were 62% for the control group and 56% for the experimental group of students. In the post-test the percentage increased to 72% for the experimental group and slightly dropped for the control group of students. The p-value was 0.025, indicated that there was a significant difference in the groups of students.

Students' performance in question 3 of the post-test was compared to question 6 in the pre-test. In the pre-test, students' performance was very poor; with the percentage of students who gave correct answers were 42% for the control group and 34% for the experimental group. Students' performance in question 3(a) of the post-test, the percentage increased to 63% for the control group and to 79% for the experimental group of students. Even though both the control and experimental group performance had increased, the percentage for the experimental group increased by 45% compared to the control group which increased by 29%. Students' performance in question 3(b), the percentage increased to 59% for the control group and to 77% for the experimental group. The experimental group increased performance

better than the control group. The p-value was 0.011, indicating significant difference in students' performance.

Students' performance in question 4 of the post-test was compared with their performance to question 11 in the pre-test. In the pre-test, the percentages of students who gave correct answers were 37% for the control group and 32% for the experimental group of students. This percentage increased slightly to 44% for the control group and to 54% for the experimental group in the post-test. Students' performance for the control group was poor in both the pre-test and post-test, whereas for the experimental group it increased slightly in the post-test. The p-value was 0.023. This indicates that the experimental group performed better than the control group.

Students' performance in question 5 of the post-test was compared to their performance to question 8 in the pre-test. In the pre-test, the percentages of students who gave correct answers were poor, with 28% for the control group and 9% for the experimental group of students. In the post-test, these percentages increased to 68% for the control group and to 91% for the experimental group. Even though both the control group and experimental group increased their performance in the post-test, the experimental increased by 81%. The p-value was 0.002. This indicates a significant difference in both groups.

Students' performance in question 6 of the post-test was compared with their performance to question 19 in the pre-test, for the experimental and control groups. In the pre-test, the percentages of students who gave correct answers were 64% for the control group and 54% for the experimental group of students. In the post-test, these percentages increased with 82% for the control group and 84% for the experimental groups. Although both groups increased performance, the experimental group increased by 30% and the control group increased by 18%.

Students' performance in question 7 of the post-test was compared with their performance in question 21 in the pre-test. Students' performances in the pre-test, was poor with 34% for the control group and 14% for the experimental group. This percentage increased to 73% for the control group and to 86% for the experimental group in the post-test. Students' performances increased in both the control and experimental groups, but the experimental group increased with 72% compared to control group with 39%. The p-value was 0.035, indicating that there was a statistical significant difference between the groups.

6.3.3 General conclusions:

Students' performance was 50% for the control group and 39% for the experimental group in the pre-test. In the post-test, the percentages increased for both groups, with 66% for the control group 79% for the experimental group. This comparison showed that there was a significant increase in performance for both groups. The improvement in students' performance is, however, much larger for the experiment group than the control group.

An improvement of students' performance may be expected in post-test because students wrote it when they were in the 2nd and 3rd year of their studies: they would have learned more chemistry. They may have also done an academic English module (AGLE).

In the pre-test, the p-values in questions 8 and 21 were below 0.05, which indicates that there were significant statistical differences in answering the questions correctly by the experimental and control groups. Although both questions were poorly answered (less than 40% of students gave correct answers), the control group performed better than the experimental group. In the post-test, seven questions had p-values below 0.05. For all the questions, except question 6, the experimental group performed significantly better than the

control group. For question 6, the p-value was higher than 0.05. p-values must be below 0.05 if there is a significant statistical difference between the groups.

The post-test results suggest that if students are instructed in the different styles which fit and accommodate their different backgrounds, and their limited English proficiency they can improve their performance in chemistry. As suggested by the constructivist approach, it is important for facilitators to guide students to formulate their own meanings, and also to allow students to make their own interpretations. Group learning can be expected to enhance students' learning because they would learn from their peers and resources. The FSI helped students to develop some thinking skills which were confirmed by their performance in the post-test. However, the results of question 4 in the post-test suggest that students struggled with understanding of verbal statements. Students need more guidance on how to draw conclusions from verbal statements. The facilitator observed that the environment and students' attitudes can also play an important role towards learning. This observation was confirmed by both SSI and FSI. In the SSI some students were not active and did not help each other to reach final conclusions, whereas in the FSI their attitudes changed which helped them to perform better in the post-test.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This chapter will summarize the results and main conclusions and findings of the study. It will also make some recommendations. Two main aspects of students' competence were tested in this study: their competence in simple language skills and verbal reasoning skills. The results from the pre-test showed that many students had difficulties with language skills and verbal reasoning skills. For example

- 30% of the students could not understand the meanings of some important non-technical words/phrases, in question 1 (such as “analyse”, “aqueous solution”, “composition of a substance”, “deduce”, “dissociation”, “emission”, “fraction”, “ratio”, “variable” and “solute”);
- 25% of the students failed to differentiate between descriptive and explanatory statements, in question 2;
- 45% of the students failed to distinguish between qualitative statements and quantitative statements, in question 3;
- 50% of the students failed to distinguish between statements which are facts, laws, definitions, theoretical statements, in question 4;
- 50% of the students failed to understand the meanings of some important words used in scientific context, in question 5 and 14 (such as “heat is absorbed”, “percentage” and “constant”)
- 45% of the students were unable to convert quantitative statements into equations, in question 6;
- 70% of the students were unable to represent the verbal information in the form of a diagram, in question 8;

- 50% of the students had difficulty in the aspects of inverse proportion reasoning, in question 11;
- 40% of the students had difficulty in the aspects of diverse proportion reasoning, in question 12;
- 40% of the students had difficulty in understanding the relationship between words used for analogical reasoning, in question 16;
- 60% of the students failed to use verbal information to draw conclusions, in question 17
- 60% of the students had difficulty in comprehension of simple concepts by applying laws and equations, in question 19;
- 70% of the students failed to use an equation to do a calculation or use verbal reasoning, in question 21 and 22;

The study also showed that a three week intervention programme given to an “experimental group” of students (a control group was also used) for rectifying some of the difficulties identified in pre-test increased students’ performance in language and verbal reasoning studied. The performance of students in the experimental group was much better than those in the control group. For example:

- The experimental group performance in the understanding of important non-technical words/phrases, increased by 15% whilst the control group dropped by 3%, in question 1;
- The experimental group performance in the ability to differentiate between descriptive statements, explanatory statements, a law, a definition and a quantitative observation, increased by 16% whilst the control dropped by 3%, in question 2;

- The experimental group increased by 45% as compared to 18% in the control group, in the ability to convert quantitative statements into equations, in question 3;
- Students' performance in the experimental group increased by 22% compared to 7% in the control group, in the understanding important aspects of inverse proportion reasoning, in question 4;
- Students' performance in the experimental group increased by 80% as compared to 40% in the control group, in the ability to use verbal information to do a simple calculation, and to represent the verbal information in the form of a diagram in question 5;
- Students' performance in the experimental group increased by 30% as compared to 18% in the control group, in the ability to apply laws and equations, in question 6 ;
- Students' performance in the experimental group increased by 74% as compared to 18% in the control group, in the ability to use defining equations, in question 7.

A comparison of students' performance in the post-test and pre-test showed that there was a significant statistical improvement in their performance for both the control and the experimental groups. Most of the questions (which are questions 1, 2, 3, 4, 5 and 7) in the post-test had p-values lower than 0.05, which showed that the experimental group performed better than the control group. The results showed that lecturers should not assume that their students are competent in the necessary language skills and verbal reasoning skills, to learn the course, even if the skills are simple. It is recommended that lecturers check this throughout their courses. Many students' failures, for example, are due to their not understanding the word "explain". Not clearly understanding the meaning of this word would result in failure at examinations because students may give a descriptive answer when what is asked in an examination question is an explanation. Another important example of students' failure is associated with direct proportion and inverse proportion reasoning. Not clearly

understanding of the words “inverse” and “directly” proportional caused difficulty for students. Students failed to differentiate between the words, and how they relate to quantitative information, which can be expressed in the form of equations, or use verbal reasoning to solve them.

7.1 Suggestions for further research

This research could be extended in the following ways:

- To test students at other institutions in the extended programmes, to check if they encounter similar problems in language and verbal reasoning skills;
- To compare the performance of the 1st and 2nd English language speakers in language and verbal reasoning skills;
- To track how students perform at higher levels in their degrees i.e., 2nd and 3rd year of study;
- To check if there is correlation between students’ language skills and their performance in chemistry.

7.2 Recommendations

The intervention program showed that active monitoring and assistance of students’ learning made me recognize that more has to be done to develop the cognitive abilities of students in the first year programme. A good learning environment must be provided during classes and tutorials. The kinesthetic model (Sprenger, 2008) postulates that if students are instructed in a style that fits them, critical thinking and higher level thinking becomes easier. This includes how students reflect and connect and apply their existing knowledge to new knowledge.

As a result of this study the researcher feels that the traditional lecture halls normally used, limits some activities which could assist students' learning, understanding and application of knowledge. In lecture halls students sit and listen in large venues and this restricts free movement and small group discussions amongst the instructor and students. In small group settings students could express themselves in their own language and interact freely with each other. It is therefore recommended that small group settings should be used in teaching, particularly for students who have difficulty understanding the medium of instruction.

The extended students are in a special programme which gives them more time to cover the content of their modules. There should thus be time available to help them to understand the language used and to become competent in verbal skills, so that they can use these skills as they progress to higher levels of learning. If the teaching style in this programme could be changed so that there are smaller groups than in the traditional method used in mainstream programmes, students might perform better. The small group settings might also assist in identifying those students who are struggling so that they can receive the necessary attention. This would lead to lower failure rates. In addition, those students in the mainstream BSc programmes who have disadvantaged backgrounds could also benefit from extra time spent on verbal skills, language skills and cognitive abilities.

7.3 Conclusion

Students need to engage in a variety of metacognitive processes to monitor and control their learning, which include assessing the task at hand, evaluating their own strengths and weaknesses and monitoring various strategies. When students develop skills to engage these processes they gain intellectual habits that not only improve their performance but also their effectiveness of learning (Nelson, 1992). Although at tertiary institutions there are not sufficient instructional materials for all the various official languages spoken in South Africa,

students should be allowed during tutorials, to discuss and clarify problems in their own language. This would help them to develop their understanding of words used in scientific contexts. It is also important for instructors to aid students in developing their cognitive abilities. Time should be spent helping students to understand words and phrases. If this results in better performance in chemistry, then it is worthwhile.

7.4 Ethics Statement

Permission to conduct the study was given by the chemistry department (North West University-Mafikeng Campus) and the Institutional Ethics Committee. The ethics number allocated for this study was NWU-00069-15-59 (certificate attached in Appendix A, page 262).

REFERENCES

- Adams, V.J., and Sewry, T. (2010). The challenges of communicating chemistry concepts to learners in Grahamstown schools. Paper Presented at the Southern African Association of Science and Technology Centres (SAASTEC) 13th conference. Saldanah (Western Cape), 22-25 November.
- Alexander, P.A. (2003). The development of expertise. The journey from acclimation to proficiency. *Educational Researcher*, 32, 10-14.
- Anderson, J.R., Conrad, F.G., and Corbett, A.T., (1989). Skills acquisition and the LISP tutor, *Cognitive Science*, 13 (4), 467-505.
- Anderson, J.R. (2000). *Cognitive Psychology and its Implication*, (5th Ed.), New York: Worth.
- Anderson, D., and Nashon, S. (2007). Predator of knowledge construction: Interpreting Students' metacognition in an amusement park physics program. *Journal of Science Education*, 91 (2), 298-320.
- Baddeley, A.D. (2000). The episodic buffer: A new component of working memory. *Trends in cognitive science*, 4, 417-423.
- Baddeley, A.D. (2001). Is working memory still working? *American Psychologist*, 56, 851-864.
- Baddeley, A. (2003). Working memory and language: an overview. *Journal of Communication Disorders*, 36, 189-208.
- Balfanz, R., (1991). Local knowledge, Academic skills, and Individual Productivity: An Alternative View. *Educational Policy*, 5(4), 343-370.
- Bandura, A., (1989). Self-Regulation of motivation and action through internal standards and goal systems. In L.A Pervin (Ed.), *Goal Concepts in Personality and Social Psychology*, Hillsdale, NJ: Erlbaum, pp. 19-85.
- Bennett, J., Lubben F., and Hogarth, S. (2007). Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching. *Journal of Science Education*, 91, 347-370.

- Bird, L.(2010). Logical Reasoning Ability and Students Performance in General Chemistry. *Journal of Chemical Education*, 87, 541-545.
- Bloom, B.S. (ed). (1956). *Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain*, New York: David Mckay.
- Bodner, G.M. (1986). Constructivism: A Theory of Knowledge. *Journal of Chemical Education*, 63 (10), 873-878.
- BouJaoude, S., Salloum, S., Abid-EI-Khalick, F. (2004). Relationships Between Selective Cognitive Variables and Students' Ability to Solve Chemistry Problems. *International Journal of Science Education*. , 26, 63-84.
- Buchel, C., Coull, J.T., and Friston, K.J. (1999). The Predictive value of changes in effective connectivity for human learning. *Science*, 283, 1538-1541.
- Burney, S.M., and Mahmood, N. (2006). A Brief History of Mathematical Logic and Applications of Logic in CS/IT. *Karachi University Journal of Science*, 34, pp. 61-75.
- Burton, N.W., Welsh, C., Kostin, I., and van Essen, T. (2009). Toward a Definition of Verbal Reasoning in Higher Education. *Educational Testing Service*, Princetown, New Jersey, pp. 1-41.
- Buttler, D.L., and Winne, P.H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, 65, 245-281.
- Carrol, J.B. (1993). *Human Cognitive abilities: A Survey of Factor-analytic Studies*. Cambridge England: Cambridge University Press.
- Cassels, J.R.T., and Johnstone, A.H. (1984). The effect of language on students' performance on multiple choice test in chemistry. *Journal of Chemical Education*, 61(7), 613-615.
- Cassels, J.R.T., and Johnstone, A.H. (1980). *Understanding of Non-technical Words in Science (Report of a Research Exercise)*. London: Royal Society of Chemistry.
- Chan, J.Y.K., and Bauer, C.F. (2014). Identifying At-Risk Students in General Chemistry via Cluster Analysis of Affective Characteristics. *Journal of Chemical Education*, 91, 1417-1425.

- Chang, J.E., and Tan, O.S. (2005). "Thinking about Thinking: What educators Need to Know". *National Institute of Education*, Nanyang Technological University, McGrawHill Education, Singapore, pp 72.
- Cracolice, M.S., Deming, J.C., and Ehlert, B. (2008). Concept Learning Versus Problem Solving. A Cognitive difference. *Journal of Chemical Education*, 85, 873-878.
- Cracolice, M.S., and Busby, B.D. (2015). Preparation for College General Chemistry: More than Just a Matter of Content Knowledge Acquisition. *Journal of Chemical Education*, 92, 1790-1797.
- Cummins, J. (1996). *Negotiating Identities: Education for Empowerment in a Diverse Society*. Ontario: California Association for Bilingual Education.
- Dalvit, L., Murray, N., and Terzoli, N. (2009). Deconstructing language myths: which languages of learning and teaching in South Africa? *Journal of Education*, 46, 33-56.
- Danili, E., and Reid, N. (2004). Some strategies to improve performance in school chemistry, based on two cognitive factors. *Research in Science and Technology*, 22, 203-226.
- Department of Basic Education: South Africa: Action Plan to 2019: Towards the Realisation of Schooling 2030: <http://www.education.gov.za/Curriculum/ActionPlan2019.aspx>, (Accessed on 12 August 2016).
- Drummond, H.P.T. (2003). Students' competence in the intellectual skills and strategies needed for learning South African matriculation chemistry effectively, Unpublished PhD-thesis, University of North West, Mafikeng.
- Ennis, R.H., (1985). "Goals for Critical Thinking Curriculum". *Developing Minds, A Resource Book for Teaching Thinking*. Association for Supervision and Curriculum Development, Alexandria, pp.54-57.
- Ericson, K.A. (2003). The acquisition of expert performance as problem solving: construction and modification of mediating mechanisms through deliberate practice. In J.E Davidson and R.J Sternberg(Eds). *The Psychology of Problem Solving*. Cambridge: Cambridge University Press, pp.31-83.

- Fensham, P. (1988). *Development and Dilemmas in Science Education*, (5th Ed.). London: Falmer.
- Ford, M.E., (1992). *Motivating Humans: Goals, Emotions, and Personal Agency Beliefs*. Newsbury PRK, CA: Sage Publications.
- Gabel, D.L. (1999). Improving Teaching and Learning through Chemistry Education Research: A look to the future. *Journal of Chemical Education*, 76(4), 548-554.
- Gardner, H. (1975). Attitude to Science: A Review. *Studies in Science Education*, 2, 1-41.
- Gee, J. (1990). *Social Linguistics and Literacies: Ideology in Discourses*. London, Falmer Press.
- Gellene, G., and Bentley, A.B. (2005). A Six-Year Study of the Effects of a Remedial Course in the Chemistry Curriculum. *Journal of Chemical Education*, 82, 125-130.
- Gentner, D., and Smith, L. (2012). Analogical reasoning. In V.S., Ramachandran (Ed.), *Encyclopedia of Human Behaviour* (2nd Ed.), Elsevier, Oxford, UK, pp. 130-136.
- Glover, D., Kolb, D., and Taylor M. (1991). Another option for chemistry dropouts. *Journal of Chemical Education*, 68, 762-763.
- Goswami, U. (1991). Analogical Reasoning: what develops? A review of research and Theory. *Child Development*, 62, 1-22.
- Graesser, A.C., Daneman, M., and Lohman, D. (1998). Exploring the SAT verbal construct in terms of basic psychological processes: Critical reading. Presentation Meeting at ETS, Princetown, New Jersey.
- Graesser, A.C., McNamara, D.S., and Van Lehn, K. (2005). Scaffolding deep comprehension strategies throughout Points and Query. Auto-Tutor and iSTART. *Educational Psychologist*, 40 (4), 225-243.
- Garnett, P.J., Garnett P.J., and Hackling M.W. (1995). Students' Alternative Conception in Chemistry: A Review of Research and Implications for Teaching and Learning. *Studies in Science Education*, 25, 69-95.
- Halpern, D.F. (2003). *Thought and Knowledge: An Introduction to Critical Thinking*. (4th Ed.). Mahwah, NJ: Erlbaum.

- Hardman, J., and Ng'ambi, D. (2003). A questioning environment for scaffolding learner's questioning engagement with academic text, a university case study. *South African Journal of Higher Education*, 17 (2), 139-146.
- Herron, J.D. (1996). *The Chemistry Classroom: Formulas for Successful Teaching*. Washington D C: American Chemical Society.
- Howie, S., and Peterson J. (2001). Mathematics literacy of final year students: South African Realities. *Studies in Educational Evaluation*, 27, 7-25.
- Jaffer, S., Ng'ambi, D., and Czerniewicz, L. (2007). The role of ICTs in higher education in South Africa: One strategy for addressing teaching and learning challenges. *International Journal of Education and Development using Information and Communication Technology*, 3 (4), 131-142.
- Johnson, D. S. (1997). Learning Technological Concepts and Developing Intellectual Skills. *International Journal of Technology and Design Education*, 7, 161-180.
- Johnstone, A.H. (1984). New stars for the teacher to steer by? *Journal of Chemical Education*, 61(10), 847-849.
- Johnstone, A.H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7, 75-83.
- Johnstone, A.H. (2006). Chemical education research in Glasgow in perspective. *Chemistry Education Research and Practice*, 7 (2), 49-63.
- Johnstone, A., and Selepeng, D. (2001). A language Problem Revisited: Methods and issues of teaching and learning. *Chemistry education: Research and Practice in Europe*, 2(1), 19-29.
- Kandarakis, A.G., and Poulos, M.S. (2008). Teaching implications of information processing theory and evaluation approach of learning strategies using LQV neural network. *WSEAS transactions on Advances in Engineering education*, 3 (5), 111-119.
- Kane, M.J., and Engle, R.W. (2002). The role of prefrontal cortex in working memory capacity, executive attention and general fluid intelligence: An individual differences perspective. *Psychonomic Bulletin and Review*, 9, 637-671.

- Kinchin, I.M., Hay, D.B, and Adams, A. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Researcher*, 42, 43-57.
- King, D. (2012). New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education*, 41(1), 51-87.
- Knapper, C. (2001). The challenge of educational technology. *The international Journal for Academic Development*, 6 (2), 93-95.
- Koballa, T.R., and Crawley, F.E (1985). The influence of attitude on science teaching and learning. *School Science and Mathematics*, 85 (3), 222-232.
- Kouider, S., and Dehaene, S. (2007). Levels of processing during non-conscious perception: a critical review of visual masking. In J., Driver, P., Haggard, and T., Shallice, (ed). *Mental Processes in the Human Brain*, Oxford. Oxford University Press, pp. 155-185.
- Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher*, 28, 16-25.
- Lawson, A.E. (1992). What do tests of formal reasoning actually measure? *Journal of Research in Science Teaching*, 29, 965-983.
- Leach, J., and Scott, P. (2002). Designing and evaluating science teaching sequences: An approach drawing upon the concept of learning demand and social constructivist perspective on learning. *Studies in Science Education*, 38, 115-142.
- Lewis, S.E., and Lewis, J.E. (2007). Predicting at-risk students in general chemistry: comparing formal thought to a general achievement measure. *Chemistry Education Research and Practice*, 8, 32-51.
- Lewis, S.E., and Lewis, J.E. (2008). Seeking effectiveness and equity in a large college chemistry course: an HLM investigation of peer-led guided inquiry. *Journal of Research in Science Teaching*, 45, 794-811.
- Lewis, A., and Smith, D. (1993). Defining Higher Order Thinking. *Theory into Practice*, 32, 131-137.

- Mayer, R. E., and Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38, 43–53.
- Marzano, R.J., (1992). *A different kind of classroom: Teaching with Dimensions of Learning*. Alexandria, Association for Supervision and Curriculum Development.
- Marzano, R.J., Brandt, R.S., Hughes, C.S. Jones, B.F., Presseisen, B.Z., Rankin, S.C., and Suther, C. (1988). *Dimensions of Thinking: A framework for Curriculum Instruction*. Alexandria, Association for Supervision and Curriculum Development.
- Maznah, A., and Zurida, I. (2006). Comprehension level of non-technical terms in science: are we ready for science in English? *Jurnal Pendidik dan Pendidikan*, 21, 73-83.
- McNamara, D.S. (2010). Computational methods to extract meaning from text and advance theories of human cognition. *Topics in Cognitive Science*, 2, 1-5.
- Mercer, N., Dawes, L., Wegerif, R., and Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal*, 30 (3), 359-377.
- Middlecamp, C., and Kean, E. (1988). Problems and “That Other Stuff”: types of chemical content. *Journal of Chemical Education*, 65, 53-56.
- Miller, G.A. (2003). The cognitive revolution: a historical perspective. *Trends in Cognitive Science*, 7, 141-145.
- Mjie, A., and Makgato, M. (2006). Factors associated with high school learners’ poor performance: a spotlight in mathematics and physical science. *South African Journal of Education*, 26 (2), 253-266.
- Mortimer, E.E., and Scott, P.H (2003). *Meaning Making in Secondary Science Classrooms*, Maidenhead: Open University Press.
- Nakhleh, M.B (1992). Why Some Students Don’t Learn Chemistry: Chemical Misconceptions. *Journal of Chemical Education*, 69, 191-196.
- Neisser, U., Boodoo, G., Bouchard, T.J.,(Jr), Boykin, A.W., Brody, N., Ceci, S.J., Halpern, D.F., Loehlin, J.C., Perloff, R., Sternburg, R., and Urbina, S., (1996). Intelligence: Known and Unknown. *American Psychologist*, 51, 77-101.

- Nelson, T.A., (1992). *Metacognition*. Boston, MA: Allyn and Bacon.
- Nentwig, P., Demuth, P., Parchmann I., Gräsel, C., and Ralle, B. (2007). Chemie in Kontext: situated learning in relevant contexts while systematically developing basic chemical concepts. *Journal of Chemical Education*, 84(1), 1439-1444.
- Nicoll, G. (2001). A report of undergraduates' bonding alternative conceptions. *International Journal of Science Education*, 23(7), 707-730.
- Owen-Smith, M. (2010) The Language Challenge in the Classroom. *Journal of the Helen Suzman Foundation*, 56, 31-37.
- Oyoo, S.O. (2011). Effective teaching of science: why what matters is the teachers' classroom language. In T., Maimala and F., Kwayisi (Eds), *Proceedings of the Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE)*. North West University, Mafikeng Campus, pp. 453-474.
- Oyoo, S.O. (2012). Language in science classroom: An analysis of physics teachers' use of and beliefs about language. *Research in Science Education*, 14, 849-873.
- Paras, J. (2001). Crisis in mathematics education, student failure: challenges and possibilities. *South African Journal of Higher Education*, 15 (3), 66-73.
- Pressley, M., and Harris, K. R. (2006). Cognitive strategy instruction: From basic research to classroom instructions. In P. A., Alexander and P. H., Winne (eds.), *Handbook of Educational Psychology* (2nd ed), Mahwah, NJ: Erlbaum, pp. 265–287.
- Pyburn, D.T., Pazicni, S., Benassi, V.A., and Tappin, E.E (2013). Assessing the relation between language comprehension and performance in general chemistry. *Chemistry Education Research and Practice*, 14, 524-541
- Rajendran, N.S. (2008). “*Teaching and Acquiring Higher-Order Thinking Skills Theory and Practice*”. Tanjong Malim Perak: Penerbit Universiti Pendidikan Sultan Idris.
- Resnick, L.B. (1987). *Education and Learning to Think*. Washington DC National Academy Press.

- Rogers, P.R., Miller, A., and Judge, W.Q. (1999). Using information-processing theory to understand planning/ performance relationships in the context of strategy. *Strategic Management Journal*, 20, 567-577.
- Seery, M.K. (2009). The role of prior knowledge and student aptitude in undergraduate performance in chemistry: a correlation-prediction study. *Chemistry Education Research and Practice*, 10, 227-232.
- Shah, P., and Miyake, A. (1999). Models of working memory: In A.Miyake and P.Shah (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* Cambridge: Cambridge University Press, pp. 1-25.
- Shapiro, A.M. (2004). How including prior knowledge as a subject variable may change outcomes of learning research. *American Educational Research Journal*, 41, 159-189.
- Watson, S. M. R., and Gable, R. A. (2011). Using knowledge of student cognition to differentiate instruction. <http://www.learnnc.org/lp/editions/everylearner/6693> (Accessed on 06 August 2016)
- Sirhan., G. (2007). Learning difficulties in chemistry: an overview. *Journal of Turkish Science Education*, 4(2), pp. 2-20.
- Shore, B.M., and Dover, A.C (2004). Metacognition, intelligence and giftedness. In R.J., Sternberg, (ed). *Definitions and Conception of Giftedness*, Thousand Oaks, Carlifornia: Corwin Press, pp. 39-45.
- Song, Y., and Carheden, S. (2014). Dual meaning vocabulary (DMV) words in learning chemistry. *Chemistry Education Research and Practice*, 15, 128-141
- Sprenger, M., (2008). *Differentiation Through Learning Styles and Memory* (2nd ed). Corwin Press, A SAGE Company, Thousand Oaks.
- Stanovich, K.E. (2003). The fundamental computational biases of human cognition: heuristics that impair decision making and problem solving. In J. E., Davidson and R. J., Sternberg (Eds). *The Psychology of Problem Solving*, Cambridge, Cambridge University Press, pp. 291-342.
- Statistics South Africa (2012). Annual Report 159/2012, Pretoria: Statistics South Africa, www.statssa.gov.za, Accessed on the 12 January 2016.

- Sternberg, S.S (1986). Toward a unified theory of human reasoning. *Intelligence*, 10, 281-314.
- Sweller, J. (2007). Evolutionary biology and educational psychology. In R. J., Carlson (ed), *Educating the Evolved Mind: Conceptual Foundations for an Evolutionary Educational Psychology*. Charlotte, North Carolina. Information Age Publishing, pp. 165-175.
- Taber, K.S. (2002). *Alternative Conceptions in Chemistry: Prevention, Diagnosis and Cure?* London: Royal Society of Chemistry, pp. 420.
- Taber, K.S. (2009). Learning at the symbolic level: In J.K., Gilbert, and D.F., Treagust, (ed). *Multiple Representations in Chemical Education*, Dordrecht: Springer, pp. 75-108.
- Taber, K.S. (2011). Constructivism as educational theory: contingency in learning and optimally guided instruction. In J., Hassaskhah (ed), *Educational Theory*, Nova, New York, pp. 39-61.
- Taber, K.S. (2013a). A common core to chemical conceptions: learners' conceptions of chemical stability, change and bonding. In G., Tsaparlis and H., Sevan (Eds), *Concepts of Matter in Science Education*, Dordrecht, Springer, pp. 391-418.
- Taber, K.S. (2013b). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice*, 14, 156-168.
- Taber, K.S. (2014). The significance of implicit knowledge for learning and teaching chemistry. *Chemistry Education Research and Practice*, 15, 447-461.
- Taylor, S., and Coetzee, M. (2013). Estimating the impact of language of instruction in South African primary schools: A fixed effects approach. *Stellenbosch Working Paper Series* No. WP21/2013.
- Tobias, S., and Duffy, T.M. (2009). *Constructivist Instruction; Success or Failure?* New York: Routledge.
- Tytler, R., (2002). Teaching for understanding in science: student conceptions research and changing views of learning. *Australian Science Teachers' Journal*, 48 (3), 14-21.

- Yaman, F., and Ayas, A. (2015). Assessing changes in high school students' conceptual understanding through concept maps before and after computer-based predict-observe-explain (CB-POE) tasks on acid-base chemistry at secondary school level. *Chemistry Education Research and Practice*, 16, 843-855.
- Yeld, N. (2001). Assessment, equity and language of learning: Key issues for higher education in South Africa. Unpublished PhD thesis, University of Cape Town, Cape Town.
- Vanides, J., Yin, Y., Tomita, M., and Ruiz-Primo, M.A. (2005). Using concept map in the science classroom. *National Science Teacher Association, Science Scope*, 28 (8), 27-30.
- Ver Beek, K., and Louters, L. (1991). Chemical language skills. *Journal of Chemical Education*, 68 (5), 389-394.
- White, R. (1977). Model of cognitive processes. *Research in Science Education*, 7, 25-32.
- Xu, X., and Lewis, J.E. (2011). Refinement of a Chemistry Attitude Measure for College Students. *Journal of Chemical Education*, 88, 561-568.
- Woldeamanuel, M., Atagan, H., and Engida, T. (2014). What makes chemistry difficult? *African Journal of Chemical Education*, 4 (2), 31-43.
- Zoller, U. (1990). Students Misunderstandings and Alternative Conceptions in College Freshman Chemistry (General and Organic). *Journal of Research in Science Teaching*, 27(10), 1053-1065.

APPENDIX A

A.1 Pre-Test: Consent Cover Letter

31-May-2013

I invite you to participate in a research study I am conducting. I am currently enrolled as a PhD student with the North West University (Mafikeng Campus). The purpose of the research is to determine the language and verbal reasoning difficulties in learning chemistry within the BSc-extended programme.

You are being asked to participate in this research study as a chemistry student. If you agree to be in this study, you will be required to participate in answering questions in the pre-test and post-test questionnaires, and possibly in the intervention programme, where there will be group discussions. The only personal information you will be asked to provide is your student number and the level of English acquired in your matric certificate, and your response will remain confidential. Data from this research will not be disclosed to anyone, other than the researcher and supervisors.

PARTICIPATION IN RESEARCH IS VOLUNTARY.

You are free to decline to be in this study, or to withdraw from it at any point. The **chemistry department** is aware of this study but does not require that you participate in this research and your decision as to whether or not to participate will have no influence on your present or future studies.

If you have any questions about this project, feel free to contact Prof H. Drummond on 018 3892317/ 2130 between (8:00 am-16:30 pm).

Agreement:

I took part voluntarily in the research, with student number_____, during my free time, and I confirm that I am above 18 years_____ (Signature).

Thank you for your attention.

Yours truly,

Ms Naledi Seheri

PhD-Candidate-Chemistry Department

North West University (Mafikeng Campus)

A.2 Post-Test: Consent Cover Letter

15-July-2015

I invite you to participate in a research study I am conducting. Previously in 2013, 2014 and (March-April) 2015 some of you participated in the study, including writing the pre-test and participating in the intervention programme. This is the last part of the research, which requires you to answer the post test questions which will take approximately **45min- 1hour to complete**.

The purpose of the research is to determine the language and verbal reasoning difficulties in learning chemistry within the BSc-extended programme. You are being asked to participate in this research study as a chemistry student. The only personal information you will be asked to provide is your student number and the level of English acquired in your matric certificate, and your response will remain confidential. Data from this research will not be disclosed to anyone, other than the researcher and supervisors.

PARTICIPATION IN RESEARCH IS VOLUNTARY.

You are free to decline to be in this study, or to withdraw from it at any point. The **chemistry department** is aware of this study and your decision as to whether or not to participate will have no influence on your present or future studies.

If you have any questions about this project, feel free to contact Prof H. Drummond on 018 3892317/ 2130 between (8:00 am-16:30 pm).

Agreement:

I took part voluntarily in the research, with student number_____, during my free time, and I confirm that I am above 18 years_____ (Signature).

Thank you for your attention.

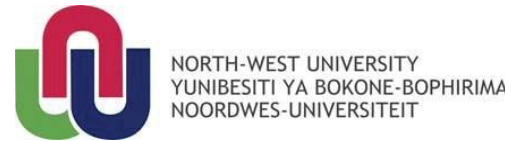
Yours truly,

Ms Naledi (Seheri) Jele

PhD-Candidate-Chemistry Department

North West University (Mafikeng Campus)

A.3 Ethics Certificate



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Institutional Research Ethics Regulatory Committee

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ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by the **Health Science Ethics Committee (FAST)**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: Difficulties in language and verbal reasoning experienced by BScExtended students.	
Project Leader: Prof H Drummond	Student: N Jele
Ethics number:	N W U - 0 0 0 6 9 - 1 5 - A 9
Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation	
Approval date: 2015-10-12	Expiry date: 2018-10-12
Category	N/A

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- x The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC:
 - annually (or as otherwise requested) on the progress of the project,
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
- x The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-IRERC. Would there be deviation from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- x The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC and new approval received before or on the expiry date.
- x In the interest of ethical responsibility the NWU-IRERC retains the right to:
 - request access to any information or data at any time during the course or after completion of the project; -
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the NWU-IRERC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC for any further enquiries or requests for assistance.

Yours sincerely

Linda du Plessis DN: cn=Linda du Plessis, o=NWU, Digitally

signed by Linda du Plessis
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Date: 2015.10.16 19:37:36 +02'00'

APPENDIX B

B.1 Pre-Test Question Paper



Faculty of Agriculture, Science and Technology

Test on competence in language and verbal reasoning skills

1. Read the questions carefully and answer all the questions.
2. Underline words/phrases that you don't understand.
3. In multiple choice questions, circle the correct answers.

Student no._____

Level of study (i.e., 1st, 2nd, and etc)_____

English at high school (i.e., 1st or 2nd language)_____

QUESTION 1

This question tests understanding of the non-technical words and phrases given in column A below, which are frequently used in chemistry. Match these words to the phrases/statements in column B

Column A (Words/Phrases)	Column B (Phrases/Statements)
1. Analyse	a. A part divided by the whole
2. Aqueous solution	b. A quantity whose value can change
3. Combustion	c. A quantity whose value does not change
4. Compare	d. A solution in which water is the solvent
5. Composition of a substance	e. Breaking up of a substance into simpler substances
6. Constant	f. Burning of a substance
7. Deduce	g. Elements/ compounds present in a substance
8. Dissociation	h. Examine or study something by breaking it down into parts
9. Emission	i. Fraction multiplied by 100
10. Excess reactant	j. More reactant than is needed for the reaction
11. Fraction	k. Occurring at the same time
12. Freezing point	l. Release of something
13. Illustrate	m. State similarities and differences
14. Percentage	n. Temperature at which a liquid becomes a solid
15. Ratio	o. The substance dissolved in a liquid to form a solution.
16. Simultaneous	p. The value of one quantity divided by another value of that quantity
17. Solute	q. To make clear by examples or pictures
18. Variable	r. To reason logically from given principles/facts.

QUESTION 2

Which of the following statements are **descriptions** and which are **explanations**? Briefly give reasons for your answers.

- (a) The volume of a gas is inversely proportional to its pressure.
- (b) The pressure of a gas is due to the continual bombardment of the walls of the containing vessel by the molecules.
- (c) The percentage of oxygen in the air is 21%.
- (d) An electric current passing through a metal is due to the flow of negatively charged particles (electrons).
- (e) The rate of diffusion of hydrogen gas is higher than that of oxygen gas because hydrogen molecules, being smaller, move at a faster speed.
- (f) In a neutral atom, the number of electrons is equal to the number of protons.

QUESTION 3

Which of the following statements are **qualitative** and which are **quantitative**? Briefly give reasons for your answers.

- (a) The density of a substance is the mass per unit volume.
- (b) A litre of water is heavier than a litre of ethanol.
- (c) The rate of diffusion of a gas is inversely proportional to the square root of its molar mass.
- (d) Ice melts at 0°C .
- (e) The rate of reaction increases in the presence of a catalyst.
- (f) Silver is a better electrical conductor than copper.

QUESTION 4

Consider each statement given below and state whether it is best considered to be an experimental **fact**, a **law**, an **opinion**, a **definition**, or a **theoretical statement**. Make comments to justify your answers.

- (a) The temperature at which water boils is 100°C .

- (b) Water dissociates to form H^+ and OH^- ions.
- (c) Effusion is the escape of a gas through a small hole.
- (d) The total mass of a system remains constant during a chemical reaction.
- (e) Density is mass per unit volume.
- (f) Matter consists of particles which are in constant motion.
- (g) The volume of a gas (at constant temperature and pressure) is directly proportional to the amount of gas.

QUESTION 5

The statements given below are not correct because the language/ concepts used are not correct. Point out clearly why they are not correct, and also modify the statements to make them correct.

- (a) When a water sample is heated, temperature is absorbed and therefore the temperature will increase.
- (b) When the temperature (T) of a substance is kept constant, it means that $T = 0$.
- (c) The percentage of girls in a class of boys and girls is 200.
- (d) The temperature of a water sample can be calculated using a thermometer.
- (e) Since 100 grams of atmospheric air contains 21 grams of oxygen, we can deduce that the percentage of oxygen in air is 21 grams.
- (f) The volume of a gas is 100 grams.
- (g) The number of molecules present in one mole of any substance is 6.0×10^{-23} .

QUESTION 6

Convert the following statements into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statements (a) and (b).

- (a) The resistance (R) of a wire is directly proportional to its length (l) and inversely proportional to its area of cross section (a).
- (b) The concentration (c_A) of a solute A in a solution is defined as the amount (n_A) of A present per unit volume (v) of the solution.
- (c) The difference between the masses of two objects A and B is 4 grams, A having the larger mass.
- (d) The sum of m_A and m_B is 13 grams
- (e) The mass fraction of A in the mixture of two substances A and B is 0.30
- (f) The mass percentage of an element A in a compound is 30%
- (g) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture
- (h) The price of N chocolates is equal to the price of one chocolate multiplied by the number of chocolates.
- (i) The ratio of the number of the girls in a class to the number of boys is 0.30

QUESTION 7

For each of the words/phrases given below, state its meaning in column 2 and the “opposite” word in column 3.

Word/Phrase	Meaning of word	Opposite word/phrase
Constant quantity		
Absorption of heat		
Proton donor		
Negative charge		
Theoretical statement		
Product of a reaction		
Exothermic reaction		

Reversible reaction		
Oxidation		

QUESTION 8

Two cars, 160 km apart on a main road, travel towards each other. The first car travels for 20km and takes a right turn and travels for 15 km. It then turns left and travels for another 30km, and then turns left again and returns to the main road. In the meantime, the other car travels 40 km along the main road.

- (i) Represent all the information given above as a diagram.
- (ii) What would be the distance between the two cars?

QUESTION 9

This question concerns the masses of 5 objects A, B, C, D and E. The mass of A is larger than the mass of B but is smaller than mass of C. The mass of D is smaller than the mass of A but is larger than mass of B. Object E has the largest mass.

- (a) Which object will have the smallest mass?
- (b) Arrange all the objects in order of increasing mass (i.e., start with the object that has the lowest mass)

QUESTION 10

Draw a right-angled triangle inside a square and then enclose the square within a circle. Finally draw a rectangle around all that you have drawn.

QUESTION 11

Three men need ten hours to tile the floor of a house.

(a). Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer)

- | | |
|--|------------------------------|
| (i) Men and floor of the house; | (ii) Three men and ten hours |
| (iii) Number of tiles and surface area of the floor; | (iv) Number of men and time |

(b). Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct).

- (i) Directly proportional; (ii) Exponential;
- (iii) Quantitative; (iv) Inversely proportional;
- (v) Qualitative.
- (c). How many hours will be needed by four men, working at the same rate, to tile the floor of this house?
- (d). Write an equation that relates the time (t) needed and the number of men (N) employed, where k is a constant.
- (e). Will 4 men need more or less time than 3 men to tile the floor of the house? (*show how you reached conclusion*)

QUESTION 12

- (a) If six chocolates cost 42 rands, calculate the number of chocolates that can be bought for 30 rands.
- (b) State the variable quantities in this problem.

QUESTION 13

- (a) Gravel is insoluble in water. Which of the following statements will be correct?
- (i) The solubility of gravel in 100g of water at 20°C is 0g.
- (ii) The solubility of gravel in 100g of water at 100°C is 10g.
- (iii) The solubility of gravel in 100g of water at 50°C is 5g.
- (iv) The solubility of gravel in 100g of water at 20°C is 10g.
- (b) The solubility of substance B at different temperatures is shown in the table below

Temperature	15°C	30°C	50°C	70°C
Solubility of B per 100g of water	40g	52g	60g	68g

Which of the following statements will be correct about substance B?

- (i) As temperature increases the solubility of substance B decreases.

- (ii) As temperature increases the solubility of substance B becomes zero.
- (iii) As temperature increases the solubility of substance B increases.
- (iv) As temperature increases the solubility of substance B stays the same.

QUESTION 14

If heat is absorbed during the reaction $A \rightarrow B + C$, which of the following statements are correct for this reaction (more than one statement may be correct; circle the correct answers.)

- a. Total energy of B and C will be greater than the energy of A.
- b. Total energy of B and C will be equal to the energy of A.
- c. The reaction will be exothermic.
- d. The reaction will be endothermic.
- e. Heat will be evolved during the reverse reaction $B + C \rightarrow A$.
- f. The reaction $B + C \rightarrow A$ will be exothermic.

QUESTION 15

A reduction reaction is defined as a reaction in which electrons are gained. Which of the following are reduction reactions (more than one statement may be correct; circle the correct answers)

- (a) $S_2O_8^{2-}(aq) + 2e^- \rightarrow 2SO_4^{2-}$
- (b) $Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(l)$
- (c) $AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$
- (d) $2Br^-(aq) \rightarrow Br_2(l) + 2e^-$
- (e) $Mn^{2+}(aq) + 4H_2O(l) \rightarrow MnO_4^-(aq) + 8H^+(aq) + 5e^-$
- (f) $KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$
- (g) $2Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$

QUESTION 16

Circle the *best* response to each question below

- a) Mass is to kilogram as volume is to
- (i) Measuring cylinder
 - (ii) Bottle
 - (iii) Metre
 - (iv) Litre
- b) Barometer is to pressure as thermometer is to
- (i) Heat
 - (ii) Temperature
 - (iii) Fever
 - (iv) Weather
- c) Square is to cube as circle is to
- (i) Radius
 - (ii) Sphere
 - (iii) Round
 - (iv) Ball
- d) Oxidation is to reduction as exothermic is to
- (i) Heat
 - (ii) Endothermic
 - (iii) Reaction
 - (iv) Release

QUESTION 17

Dineo's test marks are twice that of Pule, and Pule's marks are a half that obtained by Tshiamo. Which of the following statements will then be correct?

- (i) Tshiamo has more marks than Pule.
- (ii) Dineo has more marks than Tshiamo.
- (iii) Tshiamo and Dineo have the same marks.

(iv) Dineo has fewer marks than Tshiamo.

QUESTION 18

Dineo's test marks are twice that of Pule, and Pule's marks are a half that obtained by Tshiamo. If Pule obtained 40% which of the following statements will then be correct? (More than one statement may be correct; circle the correct answers)

- (i) Tshiamo has two more marks than Pule.
- (ii) Dineo's marks are double that obtained by Pule.
- (iii) Tshiamo and Dineo both obtained 80%.
- (iv) Dineo's marks are less than that of Tshiamo but double that of Pule.

QUESTION 19

A sugar solution contained in a vessel is diluted by adding water. Consider the following statements and state whether they are correct or not. Briefly explain your answers

- (a) Mass of sugar in the solution will remain constant.
- (b) The mass of the solution will increase.
- (c) The volume of the solution will increase.
- (d) The concentration of the sugar in the solution will decrease.
- (e) The concentration of the sugar in the solution will increase.

QUESTION 20

A student pours 1.5 ml of vinegar in a beaker, and dilutes it with 50 ml of distilled water. Consider the following statements and state whether they are correct or not.

- (a) Mass of vinegar in the solution will remain constant.
- (b) The volume of the solution will increase.
- (c) The concentration of vinegar in the solution will decrease.
- (d) The concentration of vinegar in the solution will increase.

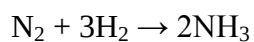
QUESTION 21

The mass fraction of oxygen in a compound is 0.20. Calculate the mass of

- (a) oxygen that will be present in 50 g of the compound.
- (b) The compound that will contain 10 g of oxygen.

QUESTION 22

Consider the following reaction, and answer the questions which follow?



- (a) How many moles of hydrogen are necessary to react completely with 0.05 moles of nitrogen?
- (b) How many moles of ammonia are produced?

B.2 Post-Test Question Paper**Faculty of Agriculture, Science and Technology**

Test on competence in language and verbal reasoning skills

1. Read the questions carefully and answer all the questions.
2. Underline words/phrases that you don't understand.
3. In multiple choice questions, circle the correct answers.

Student no._____

Level of study (i.e., 1st, 2nd, and etc)_____

English at high school (i.e., 1st or 2nd language)_____

QUESTION 1

This question tests your understanding of the non-technical words and phrases given in column A below, which are frequently used in chemistry. Match these words to the phrases/statements in column B

Column A (Words/Phrases)	Column B (Phrases/Statements)
1. Boiling point 2. Co-efficient 3. Concentrated solution 4. Decomposition 5. Dependent variable 6. Effusion 7. Experimental Data 8. Indicator 9. Mass fraction 10. Percentage yield 11. Product of reaction 12. Qualitative analysis 13. Standard solution	a. The use of experimental procedures to determine what elements are present in a substance. b. The experimental variable of a pair of variables whose value is determined by the other variable (independent). c. The ratio of the amount of product obtained in the laboratory experiment to the theoretical yield multiplied by hundred. d. A chemical substance put in a solution being titrated and whose change in colour signals the end point. e. The ratio of the mass of one component of a mixture to the total mass of that mixture. f. Any solution whose concentration is accurately known. g. End results of a chemical reaction. h. The temperature at which the vapour pressure of the liquid equals the atmospheric pressure. i. Numbers in front of formulas in chemical equations. j. Movement of gas through a very tiny opening into a region of lower pressure. k. The information obtained in an experiment often in the form of physical quantities. l. A chemical reaction that changes one substance into two or more simpler substances. m. A solution that has a large ratio of the amount of solute to the solvent.

QUESTION 2

Consider each statement given below and state whether it is best considered to be an experimental **law**, a **definition**, a **quantitative observation**, a **descriptive statement** or an **explanatory statement**

- (a) Noble gases are unreactive because their outermost valence shell is full, therefore it can neither gain or lose electrons.
-

- (b) Matter consists of tiny particles called atoms.
-

- (c) Compound is a substance formed from two or more different elements which are always combined in the same fixed proportion by mass.
-

- (d) In a chemical reaction, the atoms re-arrange but they do not break apart.
-

- (e) A sample containing sulphur and carbon is completely burned in air, and produced 0.64g of CO₂ and 0.22g of SO₂.
-

QUESTION 3(a)

Given the following statements, convert them into equations. To do this, you have to identify all the variable quantities in the statements and give symbols to them. This has been done for the three quantities in statements (a)

- (a) Density is defined as the ratio of an object mass to its volume.

Answer: Variable quantities are Density (ρ), m (mass) and volume (v).

Equation: $\rho = \frac{m}{v}$

- (b) The mass percentage of a substance A in a mixture of three substances A, B and C is defined as one hundred multiplied by the mass of A and divided the total mass of all the substances in the mixture.

- (c) Concentration is defined as the number of moles of a substance divided by the volume of that substance.

QUESTION 3(b)

Using the equations in question 4 above, calculate;

- (a) The density of 8.20ml vinegar contained in a test tube. The empty test tube had a mass of 9.2 g and after filling it with vinegar the mass was 20.2g.

- (b) The mass percentage of substance A, given that the masses of substances A=8 g, B=20g and C=26g

- (c) The concentration of 0.25 mol HCl contained in a 250 ml volumetric flask.

QUESTION 4

Four cleaners took forty minutes to clean the floor of the laboratory

(a). Which one of the following correctly states the variable physical quantities in the above statement? (circle the correct answer)

- (i) Cleaners and floor of the laboratory; (ii) Four Cleaners and forty minutes;
 (iii) Forty minutes and surface area of the floor; (iv) Number of cleaners and time

(b). Which of the following states correctly the type of relationship between the two variable quantities in the given statement? (circle the correct answers — more than one answer may be correct)

- (i) Directly proportional; (ii) Exponential;
 (iii) Quantitative; (iv) Inversely proportional;
 (v) Qualitative.

(c). Write an equation that relates the time (t) needed and the number of cleaners (N) employed, where k is a constant.

(d). Will 6 cleaners need more or less time, than 4 cleaners to tile the floor of the house? (*show how you reach conclusion*).

QUESTION 5

Three students, Katlego, Lesego and Bonolo stay in three different residences, A, B and C on a straight road. Katlego stays in residence A which is 2.4 km away from residence C where Lesego is staying. On a daily basis Katlego travels 600 metres from her residence to the fetch Bonolo who stays in residence B which is between A and C, to attend classes.

(a) What is the distance between Bonolo and Lesego's residences?

(b) Represent all information given above as a diagram.

QUESTION 6

A student pipetted 10 ml of 1M sodium hydroxide (NaOH) solution into a beaker, and diluted it with 100 ml of distilled water. Consider the following statements and state whether they are correct or not.

(a) Mass of NaOH in the solution will remain constant.

(b) The volume of the solution will increase.

(c) Mass of the solution will increase.

(d) The concentration of NaOH in the solution will decrease.

(e) The concentration of NaOH in the solution will increase.

QUESTION 7

A student performed an acid-base titration in the laboratory and obtained the following results after adding 0.12 M NaOH into an acid.

	Trial 1	Trial 2	Trial 3
Initial volume	0.50ml	11.20 ml	22.20 ml
Final volume	11.10	22.00 ml	32.80 ml
Volume added			

(a) Calculate the average volume added.

(b) Calculate the number of moles of NaOH added.
