Students’ Difficulties in Understanding Stoichiometry Concepts Taught At Advanced Level: Insights from Fife High School

BY

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A dissertation submitted to the Faculty of Science Education, Bindura University of Science Education, Bindura, Zimbabwe, in fulfilment of the requirements of the degree of Masters in Science (Chemistry) Education

November 2016
APPROVAL FORM

I the undersigned certify that I have read this project entitled Students’ difficulties in understanding stoichiometry concepts taught at advanced level: insights from Fife high school submitted in partial fulfilment of the Master of Science Education Degree in Chemistry. I further approve/disapprove its submission and recommend to Bindura University of Science Education for it to be examined.

__________________________________________

Name of Supervisor

__________________________________________

Signature of Supervisor

__________________________________________

Date Signed
DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Master’s Degree in the Bindura University of Science Education. It has not been submitted before for any degree in any other University.
ABSTRACT

This study explored how students conceptualise stoichiometry concepts taught at advanced level at Fife High School. It also aimed at identifying how students’ understanding of stoichiometry concepts compares with the received chemistry explanations. Further, it aimed at identifying the sources of the gaps between the students’ conception and received chemistry explanations. The study adopted a case study design grounded in the qualitative research paradigm. Twenty one (21) students purposively sampled participated in this study. Data generated through written tasks and task based discussions were thematically analysed. The study concluded that students have difficulties in understanding stoichiometry concepts due to alternative conceptions. The study recommends that the Ministry, through schools, should hold workshops to conscientize teachers on the existence of the alternative conceptions in students. Teachers should adopt instructional methodologies that would overcome these alternative conceptions so as to improve the performance at advanced level.
DEDICATION

This study is dedicated to my husband Isaac Madhevhu and my daughter Tabeth and three sons Isaac Junior, Mike and Anotidaiske.
ACKNOWLEDGEMENTS

Conducting and writing the study would not have been a success were it not for the contributions of many other people. I would like to extend my gratitude to all those people who helped make this dissertation a success. Firstly, my supervisor Doctor V Mpofu for mentoring me even she had a lot of work. Secondly, I would like to thank my husband Madhevhu Isaac for his moral and financial support. I also want to thank all the students who participated in the study. Lastly and most importantly I want to thank the almighty God for giving me strength to carry on despite the many obstacles I encountered.
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPROVAL FORM</td>
<td>.................................................................</td>
<td>i</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>.................................................................</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>.......................................................................</td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>....................................................................</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>.......................................................................</td>
<td>v</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>.......................................................................</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>.......................................................................</td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>.......................................................................</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF ACRONYMS USE</td>
<td>.......................................................................</td>
<td>xiii</td>
</tr>
<tr>
<td>1</td>
<td>CHAPTER ONE: INTRODUCING THE STUDY</td>
<td>1</td>
</tr>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
<td>Background of the study</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Statement of the problem</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Research questions</td>
<td>3</td>
</tr>
<tr>
<td>1.4</td>
<td>Research objectives</td>
<td>3</td>
</tr>
<tr>
<td>1.5</td>
<td>Significance of the study</td>
<td>4</td>
</tr>
<tr>
<td>1.6</td>
<td>Study assumptions</td>
<td>4</td>
</tr>
<tr>
<td>1.7</td>
<td>Delimitations of the study</td>
<td>4</td>
</tr>
<tr>
<td>1.8</td>
<td>Limitations of the study</td>
<td>5</td>
</tr>
<tr>
<td>1.9</td>
<td>Chapter summary</td>
<td>5</td>
</tr>
</tbody>
</table>
CHAPTER TWO: LITERATURE REVIEW ................................................................. 6

2.0 Introduction ................................................................................................. 6

2.1 Stoichiometry as the foundation of chemistry ............................................. 6

2.2 Stoichiometry as a complex learning area of chemistry ............................. 7

2.2.1 The mathematical nature of chemistry ................................................... 7

2.2.2 The nature of chemistry ......................................................................... 8

2.2.3 Terminology used is highly technical ................................................... 8

2.3 Recurring difficulties students encounter in learning stoichiometry ............. 8

2.3.1 Balanced chemical equations ................................................................ 9

2.3.2 Stoichiometric quantities and calculations ........................................... 9

2.3.3 The mole ratios ..................................................................................... 10

2.3.4 Identification of limiting reactant .......................................................... 12

2.3.5 Alternative conceptions ........................................................................ 12

2.4 Multiple conceptions of stoichiometry concepts ....................................... 13

2.4.1 Scientific conception ............................................................................ 13

2.4.2 Alternative conception ......................................................................... 14

2.4.3 Mixed conception ................................................................................. 14

2.4.4 No conceptual understanding ............................................................... 15

2.4.5 Theoretical underpinnings the understanding of students’ conception of stoichiometry ........................................................................ 15

2.5 The conceptual change theory ................................................................... 15
4.1 Difficulties encountered by students’ in the learning of stoichiometry ..........31

4.1.1 Balancing chemical equations.................................................................31

4.1.2 Prediction of products ..................................................................................33

4.1.3 4.1.3 Identification of state symbols .........................................................34

4.1.4 Molar ratios ..................................................................................................35

4.1.5 4.1.5 Incorrect coefficients ...........................................................................36

4.2 Stoichiometry quantities and calculations .....................................................37

4.3 Reasons behind students’ learning of stoichiometry concepts difficulties ........38

4.4 Chapter summary ............................................................................................39

5 CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS .....40

5.1 Introduction ......................................................................................................40

5.2 Summary of findings .......................................................................................40

5.3 Conclusion .........................................................................................................40

5.4 Recommendations ............................................................................................41

5.5 Chapter summary .............................................................................................41

REFERENCES .........................................................................................................42

APPENDICES .........................................................................................................48

Appendix 1: list of participating students .................................................................48

Appendix 2: BUSE introductory letter .....................................................................49

Appendix 4: MPSE authority letter .........................................................................53

Appendix 5: Provincial authority letter ..................................................................54
Appendix 6: District authority letter

Appendix 7: School authority letter

Appendix 8: Student consent form

Appendix 9: Parent/guardian consent form

Appendix 10: Written task 1

Appendix 11: Written task 2

Appendix 12: Task based discussion guide 1

Appendix 13 Task based discussion guide 2
LIST OF TABLES

Table 1: Categories of conceptions students have .................................................................13

Table 2: Fife high school enrolment per class 2016 .................................................................25

Table 3: Data: source, type, methods and tools for generating it ...........................................27

Table 4: Shows how data was generated ..................................................................................28

Table 5: Correct and incorrect responses to the prediction of products ................................33
LIST OF FIGURES

Figure 1: Conditions necessary for conceptual change.........................................................17

Figure 2: Variations in students’ conception of stoichiometry model........................................22

Figure 3: Summary of frequency of responses to items on balancing chemical equations ....32

Figure 4: correct and incorrect percentage responses to identification of state symbols ......35

Figure 5: students responses on the molar ratio in the reaction between iron (ii) ethanedioate and manganate (vii) ions ..........................................................................................................................36

Figure 6: Students incorrect and correct responses on writing coefficients in balanced equations ........................................................................................................................................37

Figure 7: Students who answered the stoichiometry quantities and calculations correctly and incorrectly ........................................................................................................................................38
LIST OF ACRONYMS USE

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPSE</td>
<td>Ministry of Primary and Secondary Education</td>
</tr>
<tr>
<td>RQ</td>
<td>Research question</td>
</tr>
<tr>
<td>STEM</td>
<td>Science Technology Engineering and Mathematics</td>
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<tr>
<td>TBD</td>
<td>Task Based Discussions</td>
</tr>
<tr>
<td>ZIMSEC</td>
<td>Zimbabwe Schools Examination Council</td>
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<tr>
<td>ZJC</td>
<td>Zimbabwe Junior certificate</td>
</tr>
</tbody>
</table>
CHAPTER ONE: INTRODUCTION

1.0 Introduction

Chemistry is one of the most important branches of science; it enables learners to understand what is happening around them. Chemistry curricula incorporate many abstract concepts, which are central to further learning in both chemistry and other sciences (Taber, 2002). The abstract nature of chemistry along with other content learning difficulties means that students require a high level skill set. Stoichiometry is one of the complex topics in chemistry that requires a series of skills, organised knowledge of chemistry and knowledge of mathematics. Students have difficulties in understanding or in carrying out calculations involving molecular weight of compounds, volumes of gases, writing of equations, balancing of equations and determination of limiting reactant. Some researchers have found that students have the knowledge of chemistry and mathematics to solve simple problems and they cannot use and link their knowledge pieces to do complex calculations. Horton (2001) found out that students who do not have conceptually organised knowledge have difficulties in understanding stoichiometry concepts. The focus of this chapter is to introduce this study on students difficulties in understanding stoichiometry concepts taught at advanced level as a case study of advanced level chemistry students at Fife High School, Gweru district in Midlands Province.

1.1 Background of the study

Many studies have been conducted in Chemistry education, all with the aim of improving the quality of Chemistry education, (Taber, 2002). Most people view chemistry as a subject that is difficult and not motivating or exciting because its teaching does not make sense to the learner sometimes (Vamvakeros, Pavlatou and Spyrellis, 2010). This is because of the way most educators approach it and their pedagogical content knowledge level. The nature of chemistry is different from other subjects as observed by Horton (2001) that it exist in three levels which are difficult to understand at the same time. These levels are macroscopic, microscopic and representational. The macroscopic level which is observed phenomenon has to be explained through the microscopic level which shows the movement and arrangement of particle behaviour.
The macroscopic and microscopic levels are translated into scientific which is now representational level. The three levels are intertwined and there is need to understand how they are related. For students to understand stoichiometry, the levels are to be addressed in stages for easy comprehension of the three levels. According to Johnstone, (2000) most subjects exist in two levels, that is the macroscopic and the representational and these are easy to learn and understand as there will be no overloading of the memory working space. Gobel (1999) is in support of the idea that school chemistry taught before 1960, laid greater emphasis on descriptive chemistry, memorisation being an important skill to achieve examination success. The microscopic interpretation and symbolic representational were left until later. Johnstone (2000) pointed out that the learner cannot cope with all three levels being taught at once. Stoichiometry depends on representational, with inadequate emphasis on the macroscopic. Stoichiometry learning requires much intellectual thought and discernment because the content is replete with many abstract concepts (Peterson and Treagust, 1989). Real understanding requires not only the grasp of key concepts but the establishment of meaningful links to bring the concepts into a coherent whole. Concepts develop as new ideas are linked together and the learner does not always correctly make such links. This may well lead to misconceptions (Ausubel, 1968).

Chemistry is often regarded as a difficult subject; an observation that sometimes repels learners from continuing with studies in chemistry as they proceed from ordinary level, advanced level and at tertiary level. This has caused a reduction in chemistry enrolments many nations.

Students often encounter difficulties in understanding stoichiometry at advanced level. This is evidenced from the Zimbabwe Schools Examination Council (ZIMSEC) reports, 2010 November paper one which reveals that most students score low marks because they could not tackle those questions which involved numerical calculations and writing of balanced equations. Bamidele, Adetunji, Awodele and Irinoye (2013) observed that students were deficient in the use of the mole concept and its application to stoichiometry. They were failing to express the mole ratio between reactants and the products of chemical reactions.

Stoichiometry cuts across all the disciplines of chemistry without understanding it, means that the advanced level pass rate would remain down hence students will not take up science related courses beyond this level. The study is important in that science and technology have become a hallmark for sustainable development in any national economy but it cannot strive without
chemistry. Students need to improve their performance in stoichiometry since it cuts across all the disciplines of chemistry and this would increase the number of students who are going to take up science related studies. The government of Zimbabwe is promoting science education through Science Technology Engineering and Mathematics (STEM). Its main objectives are to increase the number of (STEM) students who will enrol in (STEM) degree programmes at the universities in the country.

1.2 Statement of the problem

Students often encounter difficulties in understanding stoichiometry at advanced level, particularly at ordinary level, advanced level and even at degree level in Zimbabwe and elsewhere. Several researchers have found out that many students face a lot of challenges when learning stoichiometry to the extent that some end up withdrawing from doing chemistry. Many researchers concentrated on the achievement of students in stoichiometry and alternative conceptions students hold without finding the root cause of the identified problems. The focus of this study is to establish how students conceptualise stoichiometry concepts taught at advanced level and to identify how students understanding compare with the received chemistry conceptions and further it aimed to identify the source of the gaps between the students’ conception and received chemistry explanations. If the problem is not solved the performance of the students would remain down since stoichiometry cuts across all the disciplines of chemistry.

1.3 Research questions

a) How do students conceptualise stoichiometry concepts taught at advanced level?
b) How does these students’ understanding compare with the chemistry received explanations?
c) What are the sources of the gaps between the students’ conception and chemistry received explanations?

1.4 Research objectives

a) To establish how students conceptualise stoichiometry concepts taught at advanced level.
b) To identify how students’ understandings of these concepts compare with the received chemistry explanations.
c) To identify the sources of the gaps (if any) between the students’ conception and received chemistry explanations.

1.5 Significance of the study

The findings of the study are important to high school chemistry teachers when teaching stoichiometry. It is my hope that by understanding how they explained stoichiometry to their students, the teachers would then analyse their own instructional methods of delivering the stoichiometry concepts. The study is going to improve student achievement in stoichiometry and other disciplines in chemistry. As more students understand stoichiometry; more of the students might want to undergo science related studies and major in science and technology in secondary education.

1.6 Study assumptions

Students have difficulties in understanding stoichiometry at advanced level. Students’ understanding of stoichiometry concepts does not relate with the chemistry received explanations. There are sources of the gaps between the students’ conception and chemistry received explanations.

1.7 Delimitations of the study

This study was delimited geographically, methodologically and conceptually as shown below. The methodological delimitation is related to the geographical boundaries of the study. It was conducted at Fife High School in Gweru district of the Midlands Province in Zimbabwe. Further information of this study is given in the context section of chapter three. Form 6 students participated in the study. This study was conceptually delimited by defining the key terms. The first is stoichiometry, which is the basic mathematical concept that involves writing of balanced chemical equations, identification of limiting reactants in a reaction, use of mole concept in calculations (Brown, Le May & Bursten, 2013). Secondly, mole replaces the word atomic mass unit or the Avogadro number of particles Qualitative research design will be used in the study. Thirdly, balanced chemical equation contains equal number of atoms on both sides
of an equation. Fourthly, received chemistry explanations are the correct ideas that are accepted by the scientific explanations.

1.8 Limitations of the study

The findings of the study were limited by time because I had to pay attention to other duties at work such as coaching sports and delivering lessons. The findings of the lesson were also limited by financial constraints.

1.9 Chapter summary

This chapter considered the background to the research problem. I tried to establish how students conceptualise stoichiometry concepts. Research questions which when answered provide answers that satisfy the objectives of the study. This chapter also highlighted the significance of the study to classroom practitioners. Theoretical and geographical delimitations of the study were provided. The next chapter reviews related literature that informs the study.
2.0 Introduction

It is recurrent in literature that many students encounter problems in comprehending stoichiometry concepts taught at advanced level. This is literature that is relevant to this study. The purpose of literature review is to locate the study being undertaken in existing literature. In fact, the chapter discusses the relevant literature which was reviewed. The main purposes of reviewing the literature is three folded that is firstly to show knowledge gaps this study is filling, secondly to enhance the understanding of the problem under study and thirdly to develop a conceptual framework or theoretical framework of the study. Thus, this chapter is discussing literature reviewed in relation to this study. It is organised into six themes that emerged from this literature. These are: (1) writing of balanced chemical equations, (2) symbol representation of reactants and products of a chemical equation (3) use of mole ratios in calculations (4) incorrect coefficients (5) incorrect state symbols (6) stoichiometry quantities and calculations. The chapter ends with a brief summary of the issues covered.

2.1 Stoichiometry as the foundation of chemistry

Chemist and chemistry educators generally agree with Zumdahl (2002) that stoichiometry is a complex mathematical concept used to determine how much product will be produced or formed from a given quantity of reactants. Reactants are substances that are reacted to give another product. For example potassium hydroxide and sulphuric acid react to produce potassium sulphate and water. This can be symbolically expressed as follows:

Equation 2.1

KOH (aq) + H₂S (aq) → K₂SO₄ (aq) +H₂O (l)

Equation 2-1 above shows what Hand, Yang and Brusvoort (2007) mean when they say that the chemistry learning area of stoichiometry involves the study of quantitative aspects of the mass mole relationship, chemical formulas, equations and reactions. From the equation above,
one mole of potassium hydroxide is reacting with one mole of sulphuric acid to produce a mole of salt and a mole of water and for this reason the reaction ratio is 1:1. Kolb (1978) pointed out that the mole concept is central to the learning of chemistry. Stoichiometry is the foundation of chemistry, so if students cannot understand stoichiometry, they cannot understand chemistry (Paideya, 2010).

2.2 Stoichiometry as a complex learning area of chemistry

Chemistry learning requires much intellectual thought and discernment especially when doing stoichiometry because of its nature that makes it difficult. For example, (1) it is mathematical (2) it interrelates the macro, micro and symbolic levels of chemistry and (3) its terminology is highly technical concept. The factors raised above are going to be discussed in detail below.

2.2.1 The mathematical nature of chemistry

Stoichiometry is an important part of many practicing chemists’ work. It is a topic that involves calculations of the product that can be obtained from a reaction by assuming that the reaction is the only one involved and that the entire product is collected (Darley and Marlley, 1988). Stoichiometry calculations are considered to be difficult by students in general chemistry (Dierks, 1998). This is due to many different facets a student should master, such as the mole concept, balancing of chemical equations, algebraic procedures, and interpretation of a word problem into mathematical equations that serve as procedural steps which would then lead to the correct answer. Case and Fraser (1999) highlighted that students have acute difficulties in dealing with the abstract concepts required of them to perform stoichiometric calculations using the mole concept. In this vein students should be able to apply a thorough understanding of the principles involved in mole ratio and proportion calculations. Gabel and Sherwood (1984) pointed out that lack of understanding of basic mathematical principles is a real impediment to solving of stoichiometric calculations correctly using reasoning methods. Success in stoichiometric calculations is directly related to a student’s mastery of mathematical concepts such as scientific notation. This is supported by the Zimbabwe School Examination Council, Examination Board known as (ZIMSEC), in November 2010 reports that students have a tendency of getting lower or score low marks on tests that involve stoichiometric calculations. This is due to the fact that students attempt to surface learn stoichiometry concepts.
by memorising the steps necessary to solve various types of stoichiometric problems instead of understanding the overall concept.

2.2.2 The nature of chemistry

The nature of chemistry is different from other subjects as Johnstone (2000) pointed out that chemistry exists in three levels which are difficult to understand at the same time. The three levels being the macroscopic, microscopic and the representational. The macroscopic level which is the observed phenomenon has to be explained through the microscopic level that involves movement, arrangement and particles’ behaviour. The macroscopic and the microscopic are then translated into scientific notation which is now the representational level. The three levels are intertwined and there is need to understand how they are related. Except for experts in the subject, it is difficult to quickly move from one level to the other, therefore it should be done in stages for easy comprehension of the three levels. Many subjects exist in two levels, macroscopic and the representational level. These two levels are easy to learn and understand as there will be no overloading of the memory working space (Johnstone, 2000). He also pointed out that the learner cannot cope with all three levels being taught at once when doing stoichiometry.

2.2.3 Terminology used is highly technical

Novick and Menis (1976) highlighted that there is phonetic similarity of terms and this is a source of confusion to students when doing stoichiometry. This text introduces, defines and explains in great detail the terms such as relative formula mass, relative molecular mass, relative atomic mass, mole, and molar gas volume. Some of these terms are unnecessary when replaced by another. Novick and Menis (1976) believed that the terminology is a source of confusion to the students therefore educators need to put much emphasis on the terms.

2.3 Recurring difficulties students encounter in learning stoichiometry

Literature reveals that students encounter a myriad of problems in the learning of stoichiometry area of chemistry. Five of these problems are recurring. These are (1) Writing of balanced chemical equations (2) Use of mole ratios (3) Symbol representation of elements, molecules reactants and products of a chemical reaction (4) Incorrect coefficients (5) Identification of a
limiting reactant (6) Alternative conceptions stoichiometric calculations. These themes are discussed in detail in the following paragraphs.

2.3.1 Balanced chemical equations

In a study by Yarroch (1985), found out that twenty seven percent of students succeeded in solving stoichiometric problems and twenty two percent of the total interpreted and correctly used balanced equations, inferring that successfully writing a balanced equation in interpreting correctly stoichiometric coefficients provides the basis of success in solving stoichiometric problems. Niaz (1995) observed that students have difficulties in correctly interpreting a balanced equation. The different representational levels included in a balanced equation are very difficult to distinguish for students. For example, in the multiple choice tests given to them, the grade 10 students found it hard to understand that just one script, the balanced equation, can represent many experimental situations. Thus, at the end of a chemical change, students were surprised to find compounds that did not appear in the right hand side of the balanced equation. Students consider that chemical equations imply the use of stoichiometric quantities of reactants only. Niaz and Lawson (1985) stressed that balanced equations may cause students to interpret chemical equations at a microscopic level only. Laugier and Dummon (2000) reported difficulties in correctly interpreting a balanced equation. The different representational levels included in a balanced chemical equation are very difficult to distinguish for the students, for example the French chemistry curriculum warned teachers that students consider that chemical equations imply the use of stoichiometric quantities of reactants only.

2.3.2 Stoichiometric quantities and calculations

Frazer and Servant (1987) observed that even first year university students, make a lot of mistakes in solving stoichiometric problems due to confusion between different chemical quantities. Concentration, mass or volume is often used instead of the amount of matter. Many studies have shown that the mole and reaction stoichiometry concepts pose difficulties to students (Hackling and Garnett, 1985). This involves writing of balanced chemical equations, stoichiometric coefficients, limiting reagents, mole ratios of the products and reactants, theoretical yields and percentage yields (Pereira and Wijeratne, 2006). In another study by Schmidt (1990) that involved a very large sample (more than 6000 secondary education
students) sought to find out the way students carry out stoichiometric calculations. He concluded that when they make these calculations they tend to think that the proportion of the number of molecules that are combined in a chemical reaction is identical to the proportion of masses of reacting substances. He also observed that the students equalled the proportion of molar masses of the reacting substances to the proportion of combination masses, without considering the stoichiometric coefficients. With regard to the calculation of masses in chemical formulas, he pointed out that students usually do not consider that the atoms of different elements have different atomic masses.

In a study conducted later, Schmidt (1994) in order to get a sound understanding of the strategies used in the resolution of simple exercises on stoichiometric calculations emphasized that students avoid the direct calculation of amounts expressed in moles. He deduced that this may be due to the difficulties arising from the mole concept. In addition, the students examined did not use the reasoning strategies for which they had been trained, but their personal methods.

2.3.3 The mole ratios

Case and Fraser (1999) noted that students can be inclined to use a ratio equal to one between the amounts of reactants whatever the transformations. These students had developed some idea of proportion between reactants but they could not consider any other ratio but one. This suggests different levels of understanding of stoichiometry by the students. In another study, Laugier and Dumon (1990) (cited in Huddle & Pillay, 1996) implied that when students feel the need to take into account proportions in a chemical change, some difficulties may appear. They think of appropriate volumes or appropriate masses. The students failed to understand that the quantities to be taken into account are amounts of that implies the use of the mole concept. Dachsah and Coll (2007) revealed that students have an alternative framework that related to the mole ratio of the mass ratio, the limiting reagent as reactant with the smallest quantity in the form of mass and not the mole and are also using mol ratio of 1:1 for all reactants.

Pereira, Martin & Barcas (1990) carried out a survey using a large student sample from secondary education to first-year university course. They observed an increased proportion of wrong answers concerning the mole concept, that is, answers that differ from the I.U.P.A.C. definition. They concluded that there is a superficial learning of the concept. In the study
mentioned before, Dierks (1981) took as a reference the I.U.P.A.C. definitions of the mole concept (1958 and 1967), and carried out an extensive literature review, and discussed the difficulties of the introduction and the use in instruction of the mole concept. The author concluded that only provisional hypotheses can be made about the effects produced by the different definitions of the mole concept. The main learning difficulties he pointed out were the abstract character of the expression amount of substance and the diverse meanings attributed to the word mole, individual unit of mass, portion of substance, number of particles (Avogadro’s number).

Dierks (1981) in his study highlighted that there is need to clarify the meaning of the quantity amount of substance, from which derives the mole as a unit. In line with the previous review, it has been verified that the main erroneous conception among students is to identify the mole with a mass or a certain number of gas particles and to consider that the mole is a property of the molecule (Novick & Menis 1976). In another study carried out with a large sample of secondary school students, Cervellati, Montuschi, Perugini and Grimellini-Tomasini (1982) showed that students perceived the mole as a mass, and did not use it as a unit of the amount of substance. The authors connected these deficiencies to the students’ difficulties in the resolution of stoichiometric problems. According to these authors, the only possible causes of this situation must be attributed to aspects of instruction such as, the inadequate content of the curriculum; the methodology of instruction used the system of evaluation and the training of educators. With the purpose of overcoming these difficulties they pointed out the need to review the instructional methods. In order to find out whether the cause of the great difficulties encountered by secondary students when solving problems was the mole concept, or the concepts, mass, volume and number of particles. Gabel & Sherwood (1984) constructed a test on the mole concept, in which more familiar names like sugar and oranges replaced the chemical names of the substances, and where the term dozen replaced that of mole. The results of this study showed that the difficulty in the resolution of problems was probably due to the use of the term mole and of other unfamiliar terms. According to a study carried out in the U.S. by Krishnan & Howe (1994) students at second year of secondary education and first year of university had an incomplete understanding of the meaning of the term mole. In this sense, they also stated that the students often thought that the mole had to do only with molecules and not with atoms, and that the term quantity in the definition of mole meant constant mass. Staver & Lumpe (1995) investigated the understanding of the mole concept by the secondary students,
and their use of it in the resolution of problems. They verified that some identified the mole with number of particles, while others identified it with mass in grams.

2.3.4 Identification of limiting reactant

According to Boujaoude and Barakat (2000) students have problems of identifying the limiting reactant in a given reaction equation, they chose the limiting reactant at random, without really justifying their choice. For instance, they chose the one whose amount of substance is given in the question, or the one whose mass is given, or from a comparison between the different molar masses. Huddle and Pillay (1996) reported more systematic mistakes. A few students claimed that the limiting reactant is the compound with the smallest stoichiometric coefficient in the balanced equation. Other students decided that the limiting reactant is the one whose amount of substance is the smallest. One student even wrote that the limiting reactant is equal to the least number of moles. The assumption is that these students generalize from the case of an equimolar reaction, such thinking can be reinforced by the teaching, when using an algorithmic approach to stoichiometry in particular cases such as equimolar reaction.

2.3.5 Alternative conceptions

Many studies on stoichiometry dealt with students’ alternative conceptions (Mitchell and Gunstone, 1984; Schmidt1990; Huddle and Pillay, 1996; BouJaoude and Barakat, 2000). Students equate the mass ratio of atoms in a molecule with the ratio of the number of these atoms and the mass ratio with the molar mass ratio (Schmidt, 1990) students calculate the molar mass of a given substance by summing up the atomic masses and then multiplying or dividing this sum by the coefficient of the substance in the chemical equation, others do not understand the significance of the coefficients in a chemical equation at all that students equate the mass ratio of atoms in a molecule with the ratio of the number of these atoms and the mass ratio with the molar mass ratio (Schmidt, 1990) students calculate the molar mass of a given substance by summing up the atomic masses and then multiplying or dividing this sum by the coefficient of the substance in the chemical equation, others do not understand the significance of the coefficients in a chemical equation.
2.4 Multiple conceptions of stoichiometry concepts

Studies have revealed that students hold multiple conceptions of stoichiometry. Table 1 depicts four main categories of these conceptions.

Table 1: Categories of conceptions students have

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<tr>
<td>Scientific conception</td>
<td>Students show all of the scientific conceptual understanding criteria.</td>
</tr>
<tr>
<td>Alternative conception</td>
<td>Students include a subset of conceptual understandings that are in conflict with scientific aspects of the stoichiometry concepts. It emerged from the generated data.</td>
</tr>
<tr>
<td>Mixed conception</td>
<td>Students show a subset of conceptual understandings that are in conflict with scientific aspects with a subset of correct scientific conceptual understanding.</td>
</tr>
<tr>
<td>No understanding</td>
<td>Students do not show enough evidence in their written responses to judge the students’ understanding as scientific or alternative conception.</td>
</tr>
</tbody>
</table>

The categories of students’ conception are discussed in detail in paragraphs below.

2.4.1 Scientific conception

According to Gabel and Bunce (1994) scientific conception is the understanding of the ideas and theories that form the backbone, of the scientific community. For students to have scientific conceptions they must learn the qualitative conceptual models before they learn the mathematically-based models that are useful to scientists. Horton (2001) pointed out that for
students to have scientific conception; there is need for them to use the concepts to incorporate new ideas, to differentiate between ideas or to apply the concepts especially in solving problems. Scientific conception occurs when students provide answers that are in agreement with the received view of chemistry. The students who participated in the study showed scientific conception on the direction faced by arrows in the reaction equation.

2.4.2 Alternative conception

Driver (1989) revealed that students’ conceptions are often inconsistent with the scientific conceptions they are expected to learn. These conceptions are referred to as alternative conceptions. Alternative conceptions mean a conception which differs significantly from that which is socially agreed by the scientific community (Gilbert, 1983). Students develop different conceptions from those they that they are expected to learn and that these conceptions may be highly resistant to change. Alternative conceptions are often parallel explanations of natural phenomena. Students come to school with non-traditional ideas that deal with the natural world that are highly resistant to change and strongly influence learning. The students who participated in this study were failing to write balanced equations and they were also failing to carry out stoichiometric calculations and this means that they have alternative conceptions that are not in agreement with the scientific concepts that are accepted by the scientific community.

2.4.3 Mixed conception

Mixed conception occurs when students show a mixture of both a subset of scientific conception and part of alternative conception. Dahsah and Coll (2007) highlighted that students show alternative conceptions when they fail to solve numerical problems correctly. In the study students failed to calculate the composition of the gases in the mixture in written task one questions (1d) and (1e). On the other hand students who participated in the study were showing scientific conception on questions (2a), (2b) and (2c) where they were able to carry out calculations on molar mass and molar volume. The students also indicated that they have correct scientific conception when drawing the correct direction of arrow when writing equations.
2.4.4 No conceptual understanding

This category emerged from the data gathered where students were not able to give enough evidence or incorrect responses and these are difficult to categorise. Students who participated in the study were showing no conceptual understanding on written task 1 on questions (1d) and (1e) where most of the students were just leaving the items without answers.

2.4.5 Theoretical underpinnings the understanding of students’ conception of stoichiometry

There are many learning theories that can be used to understand how students learn in general and specifically how they learn stoichiometry. However, many of the studies I have cited earlier on are silent in the theory they used to frame their studies. However, in this study I selected three theories to complement each other in explaining why students understand stoichiometry concepts differently. These are conceptual change, the constructivists’ theory and the cultural border crossing.

2.5 The conceptual change theory

Students do not enter classroom as blank slate (Horton, 2001). This means these students come to school with already formed ideas on many topics including on how they view and interpret the world around themselves. This is what is referred to as students’ background knowledge. Such background knowledge relate to the learning area encountered by students in a different ways. On one hand some background knowledge may be contrary to the knowledge being learnt. On the other hand are those that are aligned to this new knowledge being learnt.

More than often research has shown that students whose ideas conflict with new information are called to engage in the process of conceptual change. These studies have also shown that in such situations conceptual change is difficult to accomplish because such students tend to in favour of their existing understandings of the world. This is because learning the unfamiliar and conceptually understanding the subject matter already provides a large challenge. Later alone, unlearning what one has always known to accommodate new knowledge will be even be more problematic. Literature then butch all understanding of a scientific subject matter such as stoichiometry that are at loggerhead with the received view of stoichiometry misconceptions or alternative conceptions. It can be argued that understanding how students form concepts from their background knowledge can inform how teachers can help in shifting their
understanding of concepts to that of the received view. Students ‘conceptual ideas are based on personal experiences and require real changes in thinking but students are not open to new ideas (Posner, Strike, Hewson, and Gertzog, 1982). These authors propose the conceptual change theory with the view that it is a combination of two theories grounded in the history and philosophy of science (Kuhn, 1957) and developmental psychology (Piaget, 1977).

Kuhn’s work, the structure of “The structure of scientific revolutions” describes how scientific discoveries by various individuals coupled with historical crises caused the scientific revolutions that finally led to new scientific methodologies and globally accepted world views. Posner et al made a statement that they are using Piaget’s terms but not borrowing the concepts in total. Piaget’s work describes how learners learn through the assimilation and accommodation of knowledge. Posner et al (1982) suggested that the conditions for the accommodation of new concepts are similar to Kuhn’s conditions for the acceptance of a new scientific paradigm.

The process of doing science that Kuhn typified as assimilation of scientific results within a paradigm is similar to the way that Piaget described how individual acquire knowledge. The paradigm shift caused by the scientific revolution can then be compared to the accommodation of new knowledge in an individual that leads to a change of that individual’s conceptual framework. Thus using the words of Posner et al, assimilation refers to the use of existing concepts to deal with new phenomena and accommodation involves replacing or reorganising the learner’s central conceptions in that sense accommodation signifies a radical change involving the abandonment of the existing conception and the acceptance of a new conception. There are four conditions to be met for conceptual change to occur (Posner et al, 1982). These conditions are shown in Figure 1 below.
Figure 1: Conditions necessary for conceptual change

Figure 1 shows that the conditions that are to be met in order for conceptual change to occur. Firstly, there must be dissatisfaction with the existing conceptions. It is the process
of building a new cognitive structure, or modifying an existing structure, requires active participation and effort on the part of the learner. A student is unlikely to make such an effort without motivation, and this arises from dissatisfaction with the present concept, usually due to a lack of faith in the capacity of the existing concept to solve presented problems or resolve anomalies. Secondly, a new concept must be intelligible. This is not to say that it must be fully understood, but rather that the student must be able to grasp how experience can be structured by a new concept sufficiently to explore the possibilities inherent in it. Thirdly, a new concept must appear initially plausible. The new concept needs to hold on the promise of being able to resolve the problems that led to dissatisfaction with the current concept. To add more, the new concept will appear plausible if it appears consistent with other existing knowledge. Fourthly, a new concept should suggest the possibility of a fruitful research program. That is, it should actually resolve the problems that the original concept could not. In addition, it should have the potential to be extended, opening up new areas for investigation.

Posner et al (1982) distinguished between the assimilation and accommodation when dealing with new phenomena. Assimilation involves the use of existing concepts to deal with the new phenomena. By contrast, accommodation occur when the new phenomena cannot be assimilated, and replacement or reorganisation of existing concepts occur. The above conceptual change model describes the process of accommodation. The model has direct implications regarding how to construct instruction to achieve conceptual change. Instruction should be designed to present anomalies so as to create cognitive conflict. This will create a disequilibrium, which leads to dissatisfaction with the existing concept, and ultimately to a willingness to accommodate a new concept. The teacher is required to adopt the additional role of an adversary in the sense of a Socratic tutor. In this role, the teacher confronts the students with the problem arising from their attempt to assimilate new conceptions. Since conceptual change requires effort on the part of the student, the issue of motivation needs to be considered.

Dole and Sinatra (1998) pointed out in their cognitive reconstruction of knowledge model, dissatisfaction with an existing concept is only one motivating factor that influences whether a student will put in the effort needed for conceptual change to occur, they identified other factors including social context and personal relevance. So, for instance, if a student is studying an area merely to pass an exam (an extrinsic motivation) in an area that they see as peripherally relevant to their careers, they may recognise the existence of a conflict but lack the motivation
to do anything about it, as it lacks a personal relevance for them. The conceptual change theory can be used to address the issue of alternative conceptions.

2.5.1 The constructivist theory

This section focuses on how the constructivist theory affects the students in their learning of stoichiometry concepts. Bruner (1966) pointed out that learning is an active process in which students construct new ideas or concepts based upon their current or past knowledge. The student selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure such as schema or mental models provides meaning and organization to experiences and allows the individual to go beyond the information given.

As far as instruction is concerned, the teacher should try and encourage students to discover principles by themselves. The instructor and student should engage in an active dialog as in, Socratic learning. The task of the teacher is to translate information to be learned into a format appropriate to the learner's current state of understanding. Curriculum should be organized in a spiral manner so that the student continually builds upon what they have already learned.

Bruner (1966) highlighted that a theory of instruction should address four major aspects: firstly predisposition towards learning, secondly the ways in which a body of knowledge can be structured so that it can be most readily grasped by the student, thirdly the most effective sequences in which to present material, and fourthly, the nature and pacing of rewards and punishments. Good methods for structuring knowledge should result in simplifying, generating new propositions, and increasing the manipulation of information. When the teacher makes use or follows the constructivist ideas in delivering lessons it would not be a challenge to the students to understand stoichiometry concepts. The cultural border crossing will be discussed in the following section.

2.5.2 The cultural border crossing

This model frames learning in terms the differences between the home culture and the school culture. Jegede (1995) explained cognitive conflicts arising from cultural differences between students' life-world and school science in terms of collateral learning. One major influence on science education identified by students in developing countries is their feeling that school
science is like a foreign culture to them (Maddock, 1981). Their feeling stems from fundamental differences between the culture of Western science and their indigenous cultures (Aikenhead, 1997). Many students in industrialized countries share this feeling of foreignness as well (Aikenhead, 1996; Costa, 1995). Cultural clashes between students’ life-worlds and the world of Western science challenge science educators who embrace science for all, and the clashes define an emerging priority for the 21st century to develop culturally sensitive curricula and teaching methods that reduce the foreignness felt by students. Cultural clashes can happen to anyone and these influences the way students conceptualise stoichiometry concepts. Science students are expected to construct scientific concepts meaningfully even when those concepts conflict with indigenous norms, values, beliefs, expectations, and conventional actions of students’ life-worlds (Aikenhead, 1997; Cobern, 1996; Jegede, 1995). These cultural clashes can create hazards for many students. In response to such hazards, students understandably invent ways to avoid constructing scientific knowledge, or students conveniently store the constructed scientific knowledge in their minds out of harm’s way from interfering with their life-world experiences.

Costa (1995) studied students’ varied success at moving between the culture of their family and the culture of their science classroom. She found out that these transitions are smooth when the cultures of family and science are congruent; transitions are manageable whenever the cultures are somewhat different, and transitions tend to be hazardous when the cultures are diverse, and transitions are virtually impossible when the cultures are highly discordant. In other words, success in science courses depends on the degree of cultural difference that students perceive between their life-world and their science classroom, how effectively students move between their life-world culture and the culture of science or school science, and the assistance students receive in making those transitions easier. Wolcott (1991) pointed out that to learn science is to acquire the culture of science. In order to acquire the culture of science, students must travel from their everyday life-world to the world of science found in their science classroom. Students’ flexibility, playfulness, and feelings of ease in the world of science will help determine the smoothness with which students cross the border into the culture of science. This smoothness will likely affect the degree of culture acquisition that takes place. Different cultural processes are involved in the acquisition of science culture. When the culture of science generally harmonizes with a student’s life-world culture, science instruction will tend to support the students’ view of the world, and the process of enculturation tends to
occur (Hawkins & Pea, 1987). This process is characterized by smooth border crossings and is experienced by the type of student Costa (1995) called Potential Scientists. However, when the culture of science is generally at odds with a student’s life-world, science instruction will tend to disrupt the student’s world view by trying to force that student to abandon or marginalize his or her life-world concepts and reconstruct in their place new (scientific) ways of conceptualizing. This occurs through assimilation and it can alienate students from their indigenous life-world culture, thereby causing various social disruptions (Baker & Taylor, 1995; Maddock, 1981).

The success in science courses depends on how effectively pupils move between their life-world culture and the culture of science, other implications for teaching science (complementary to, and overlapping with, Jegede's ecocultural paradigm) proposed the following (Aikenhead, 1996) make border crossings explicit for pupils, facilitate these border crossings, promote discourse so that pupils will be talking in their own cultural interpretive framework as well as in the framework of Western science without cultural violence immersed in either the pupils' indigenous life-world culture or the culture of science, and also cognizant about which culture they are talking in at any given time. The teacher should substantiate and build on the validity of pupils' personally and culturally constructed ways of knowing and should also teach the canonical content of Western science and technology in the context of science’s social, military, political, colonial and economic roles. Jegede (1995) suggested that a conceptual ecocultural paradigm consists of the following features, generating information about the pupil's everyday environment to explain natural phenomena followed by identifying and using the Indigenous scientific and technological principles, theories, and concepts within the pupil’s community and lastly teaching the typical values of the Indigenous community in relation to, and in the practice of, science and technology as human enterprises. All three features relate to Lugones (1987) criteria for feeling at ease in a foreign culture; the features should help pupils negotiate their cultural borders into school science. In short, the ecocultural paradigm acknowledges cultural differences, provides emotional support for pupils, and sets the stage for cross-cultural instruction.

### 2.6 Variations in students’ conception of stoichiometry

Figure 2 below frames the how the students’ conceptions of stoichiometry vary. It further provides the sources of such variations. This frame was drawn from the discussions above.
According to this model stoichiometry concept included balanced equations, and these are the ones the students at advanced level are learning and expect to conceptualise. However, research has revealed that these students exhibit varied understandings of such concepts. The main categories of such conceptions are received, alternative, mixed and incorrect conceptions. In turn, such conceptions have found to rooted two three main types of background knowledge. These are previous taught concepts, gender variation and cultural background.

### 2.7 Chapter summary

This chapter looked at literature related to recurring difficulties students encounter in learning stoichiometry. Students were not familiar with writing of balanced equations, prediction of products of reactions between different reactants, giving state symbols of both reactants and products and the mole concept. All the students agreed that stoichiometry concepts are difficult to conceptualise because of their abstractness in nature.
CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This study aimed at establishing how students conceptualise stoichiometry concepts taught at advanced level. It also aimed at comparing students’ understanding of stoichiometry concepts with the western received explanations and also to explain the gaps between students’ conception and chemistry received explanations of stoichiometry. This chapter focuses on the methodology that the study employed. All research adopts a research methodology commensurate to the problem under investigation. According to Creswell (2003) research methodology is the systematic, theoretical analysis of the methods applied to the field of the study and the research methodology offers the theoretical underpinning for understanding set methods. Franklin, (2012) suggested that the methodology section of a research answers two main questions, that is, (1) How was the data collected or generated? (2) How was the data analysed? In order to achieve the objectives of the study stated in section 1.4 and answer the research questions asked in chapter one, this chapter presents and describes the components of the methodology. These components which form the organisation of the chapter are research design, the context of the study, participation in the study, the method used to generate and analyse data, and highlights on how findings are presented in chapter four. This chapter is concluded by summarising the main issues of discussion.

3.1 Paradigm deriving the research

All research is paradigmatic driven. Kuhn (1970) described paradigm as the underlying assumptions and intellectual structure upon which research and development in a field of inquiry is based. It is a world view within which researchers work. The qualitative research design was used in this research in order to enable the researcher to generate relevant data from the participants. I used the case study research design to triangulate the research designs.
(Chiromo, 2006) defines triangulation as collecting information from a diverse range of individuals and settings using a variety of methods.

3.2 Research design

In order to address the research problem or answer the research questions posed in chapter one, a case study design has to be adopted. Research design is a detailed outline of how an investigation will take place. It guides on how data is collected and analysed as well as the methods that were used. Case study is a form of qualitative research that focuses on providing a detailed account of one or more cases (Creswell, 1994). A study that is designed as a case looks at individuals or a group of participants. In this case a group of a group of individuals was used in form of a class of students doing chemistry at advanced level case study allows researchers to study research problems in the local context in which it existed.

3.3 Context of the study

The study was conducted at Fife (Pseudonym) High School. It is a boarding school but in the boarding section there are boys only and girls are day scholars. It offers a three level educational curriculum, that is, at the junior level (Form 1 and 2), the ordinary level (Form 3 and 4) and the advanced level (Form 5 and 6) respectively.

Fife High School’s science curriculum offers chemistry in both pure form and in combined form. Chemistry in combination with Biology and Physics is offered at Zimbabwe Junior Certificate (ZJC) level as General Science. Chemistry in combination of Biology and Physics is also offered at ordinary level in the integrated science. The pure Chemistry curriculum is also offered at Ordinary and Advanced level. Pure Chemistry is being done by three classes from form one to six. Table 3-1 below shows the Fife High School enrolment per class as per Ministry of Primary and Secondary Education.
Table 2: Fife high school enrolment per class 2016

<table>
<thead>
<tr>
<th>JUNIOR CERTIFICATE</th>
<th>ORDINARY LEVEL</th>
<th>ADVANCED LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORM 1</td>
<td>FORM 2</td>
<td>FORM 3</td>
</tr>
<tr>
<td>E</td>
<td>W</td>
<td>C</td>
</tr>
<tr>
<td>49</td>
<td>51</td>
<td>53</td>
</tr>
</tbody>
</table>

The classes in bold font, F3E, F4E, L6SC and U6SC in table 2 above are the only classes doing pure chemistry at Fife High School. The table shows that pure sciences are also offered at Advanced level and only 21% of the school population is specialising in sciences.

3.4 Participants

Twenty one (21) students in U6Science class participated in this study (see Table 2 above). This class was selected because of two basic reasons. It was the class that was doing chemistry and I was teaching chemistry to these students. This made negotiation of their participation easy as I had built good relationships with them before undertaking my study.

The twenty one students who participated in the study were selected according to those who were doing chemistry in U6 science and that their parents or guardians had given them consent to participate in the study and thirdly they had volunteered to participate in the study. The list of students who participated is provided in Appendix [1].

As discussed above my choices of school, the class and students were all based on defined criteria. I used purposive sampling. Purposive sampling is a procedure in which the researcher samples whoever he or she believes to be representative of a given population (Springer, 2010). Purposive sampling thus involves researchers handpicking the cases to be included in the sample that he or she regards as rich sources of information relevant to the problem understudy (Chiromo, 2006).
3.5 Research authority

The study was obtained based on the following ethical considerations: informed and voluntary consent, confidentiality, anonymity and right to withdraw from the study the responsible authorities from whom I applied for authority. The researcher alerted the participants on the principle of informed consent. They were also reassured of their rights during the study and that their identity will be anonymous. The participants were also informed that their participation is voluntary and that if they want to withdraw from the study anytime they are free to do so. According to Chiromo (2006) research ethics are a set of principles that people use to decide what is right and what is wrong. This implies that I had to get a clearance letter for permission to conduct the study from various stakeholders: Ministry of Primary and Secondary Education (MPSE), Provincial and District education departments, school, parental and individual consent before carrying out the study. I obtained an introductory letter from Bindura University of Science Education as shown in Appendix 2. The letter introduced me to the responsible authorities from whom I applied for authority. The application letter I used is shown in Appendix 3. I was given authority from the (MPSE) and at Provincial, District, School and Department level as shown in appendices 4 and 5. The students also gave their consent and that of their parents to participate in research as shown in appendices 6 and 7.

3.6 Generating research data

This section aims at showing the nature of data that was generated, the sources of the data where it was generated from, the methods and tools used to generate and record it and the procedures of how this data was generated. This information is summarised in Table 3-2 below. Generating this data aimed at answering the research questions (RQ) asked in Chapter One. These are asked again here for easy references.

a) How do students conceptualise stoichiometry concepts taught at advanced level?

b) How comparable are these advanced level students’ understanding of stoichiometry concepts with the western received explanations?

c) What are the sources of the gaps between the students’ conception and chemistry received explanations?
Table 3: Data: source, type, methods and tools for generating it

<table>
<thead>
<tr>
<th>R Q</th>
<th>SOURCE</th>
<th>METHOD</th>
<th>TOOL</th>
<th>NATURE OF DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GENERATION</td>
<td>CAPTURING</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Student</td>
<td>written task</td>
<td>Task cards</td>
<td>Written responses</td>
</tr>
<tr>
<td>2</td>
<td>Student</td>
<td>Written task</td>
<td>Task cards</td>
<td>Written responses</td>
</tr>
<tr>
<td>3</td>
<td>Student</td>
<td>Task based Discussion(TBD)</td>
<td>TBD guide</td>
<td>Field notes</td>
</tr>
</tbody>
</table>

Each of these main aspects of data generations are elaborated in the following sections

3.6.1 Data sources

Table 3 shows that the data was generated mainly from the students. This is done to establish how students conceptualise stoichiometry concepts taught at advanced level and to explain the gaps between student’s conception and chemistry received explanations of stoichiometry. The characteristics are detailed in section 3.4 above.

3.6.2 Methods of generating data

Two methods which were used to generate data in this study are discussed in turn below. These are written tasks and task group discussions /revisions. The written task method is described as a piece of work in which you demonstrate your understanding of the course work. It was chosen because of its ability to assess the understanding of the course work. The method was chosen because of its ability to assess the understanding of stoichiometry concepts. Written tasks can be used as a powerful tool to identify the learning problems and their sources. Two sets of written tasks were self-developed. The items were selected from ZIMSEC past examination
papers, Chemistry textbooks. Their selection was guided by the ZIMSEC Chemistry syllabus code 9189. Each written task was administered as a class work within a double lesson. In a double lesson a task can be written and revised. I invigilated the writing process of the tasks.

The writing process of the written task was followed by marking. The marked answer scripts were analysed to determine the correct and incorrect response. The incorrect responses were then analysed further to see the nature of the incorrectness. Task group discussion was used to find out why students incorrectly responded to the tasks. A task group discussion is a group of individual with similar interests who gather either formally or informally to bring up ideas, solve problem or give comments (Webster online). The analysis of the written task was followed by a task group discussion. Two sessions of TBD were guided by the TBD guide shown in Appendices 12 and 13. They were self-developed as was with the written tasks.

3.7 Procedures of generating data

Table 4 below summarised how the generation of data progressed.

**Table 4:** Shows how data was generated

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>DATE</th>
<th>DURATION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written task 1</td>
<td>15/09/16</td>
<td>35 minutes</td>
<td>Work was covered</td>
</tr>
<tr>
<td>Marking and analysis 1</td>
<td>15/09/16</td>
<td>15 minutes</td>
<td>Work was covered</td>
</tr>
<tr>
<td>Task based discussion 1</td>
<td>15/09/16</td>
<td>35 minutes</td>
<td>Work was covered</td>
</tr>
<tr>
<td>Written task 2</td>
<td>16/09/16</td>
<td>35 minutes</td>
<td>Work was covered</td>
</tr>
<tr>
<td>Marking and analysis 2</td>
<td>16/09/16</td>
<td>35 minutes</td>
<td>Work was covered</td>
</tr>
<tr>
<td>Task based discussion 2</td>
<td>16/09/16</td>
<td>35 minutes</td>
<td>Work was covered</td>
</tr>
</tbody>
</table>
Table 4 shows two sets of written tasks that were administered to the students as individuals. In written task 1, students were asked to write balanced chemical equations with state symbols and correct formula of both the reactants and products (see Appendix [10]). The administration of the individual work or class work was followed by marking and analysis was done to find the correct and incorrect responses. The incorrect responses were further analysed to identify their nature of incorrectness. Each analysis of the written task was followed by a task based discussion. Task based discussion 1 followed after marking and analysis of written task 1.

In the written task 2 students were asked to show correct interpretation of the mole ratio and perform calculations (see Appendix [11]). As before the written task were marked and analysed so that incorrect responses will be analysed further. The written task questions were selected from ZIMSEC past examination papers and the writing sessions we monitored.

3.8 Nature of data generated

The responses to written tasks generated text data. The TBD were field noted and also produced text data. Burgess (1999) described field notes as notes created by the researcher during the act of qualitative fieldwork to remember and record the behaviour, activities, events and other features of an observation. Field notes were meant to be read by the researcher to produce meaning and an understanding of phenomenon. The analysis of qualitative research data begins in the field, at the time of observation. According to Coffey and Atkinson (1996) the generated data is organised and categorised into concepts. The data is then connected to show how one concept may influence another. After corroboration by evaluating alternative explanations and searching for negative cases the data can now be reported.

3.9 Data analysis

This text data was content analysed for recurrence of problems and reasons behind such problems. This means I looked for problems and reasons which were appearing many times in this text data. Such data analytical procedures are typical of qualitative research. The incorrectness of written responses was grouped according to the question asked. The class revisions or discussions were studied to get the reasons behind each problem area
3.10 Presentation of findings

The data analysis results are presented in the next Chapter Four in form of tables, diagrams and descriptions and interpretations. Direct quotes from student voices are in some instances provided as evidence of what the student involved in group discussion voiced.

3.11 Chapter summary

The chapter outlined the research methodology which the study adopted. The main aspects which were discussed in this chapter were the case study design which was used, the context in which the study took place, the students who participated in the study and how they were selected. Methods of collecting, analysing and presenting data were also discussed. How ethics were taken into consideration was also discussed. The next Chapter presents and discusses the findings of this study.
4.0 Introduction

This chapter presents the research findings of data analysis which was done in chapter three. The study sought to find answers to the three research questions that were asked in chapter one. The first question asked: How do students conceptualise stoichiometry concepts taught at advanced level? The second question asked: How does these students’ understanding compare with the chemistry received explanations? The follow up and the third question asked: What are the sources of the gaps (if any) between the students’ conception and received chemistry explanations? Thus, this chapter is organised in accordance to the findings which were answering these questions. The following section presents and discusses students’ problems in stoichiometry. This is followed by the reasons behind these learning problems. The results are discussed before concluding the chapter with a summary of its contents.

4.1 Difficulties encountered by students’ in the learning of stoichiometry

Six themes emerged from the common difficulties encountered by students in learning stoichiometry concepts from the content analysis of data. These are: balancing of chemical equations, Prediction of products, correct formula of products and reactants, use of mole ratio in calculations, missing state symbols, interpreting chemical equations and calculating stoichiometry quantities of reactants and products of a chemical reaction. Each theme is presented and discussed below.

4.1.1 Balancing chemical equations

Figure 3 shows summary of the frequency of responses to items on balancing of chemical equations.
Figure 3: Summary of frequency of responses to items on balancing chemical equations

These results emerged from written task 1 in Appendix 10 where students were asked to write balanced chemical equations. As Figure 3 is illustrating, only 5% of the students correctly balanced the chemical equation for the reaction between copper and nitric acid in question 1a. For example, Fadzai Moyo could not balance the chemical equation for the reaction between copper and nitric acid. She wrote it as:

\[ 2\text{NO}_3^- + \text{Cu} \rightarrow \text{Cu(NO}_3)_2 + \text{NO} \]

Instead of \[ 3\text{Cu} + 8\text{HNO}_3 \rightarrow 3\text{Cu(NO}_3)_2 + 2\text{NO} + 4\text{H}_2 \]

Only 19% of the students correctly balanced item 1b. The majority of students failed to balance the reaction between aluminium oxide and sodium hydroxide. Brian Chikumba failed to balance the equation. He wrote it as:

\[ \text{Al}_2\text{O}_3 + \text{NaOH} \rightarrow \text{NaAl(OH)}_4^{-1} \]

Instead of \[ \text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl(OH)}_4 \]

The third question on the reaction between concentrated sulphuric acid and solid iodine was the most difficult to all the students because not a single student managed to answer the question correctly. Wigan Spurs balanced it as:
Instead of $5\text{H}_2\text{SO}_4 + 8\text{KI} \rightarrow 4\text{I}_2 + \text{H}_2\text{S} + 4\text{K}_2\text{SO}_4 + 4\text{H}_2\text{O}$

4.1.2 Prediction of products

The study revealed that students who participated in the study had challenges on predicting the products of reaction. Table 5 below shows the frequency of incorrect and correct responses to items that required these students to predict the products.

**Table 5: Correct and incorrect responses to the prediction of products**

<table>
<thead>
<tr>
<th>REACTION</th>
<th>CORRECT</th>
<th>INCORRECT</th>
<th>BLANK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a) Copper and nitric acid</td>
<td>33%</td>
<td>67%</td>
<td>0%</td>
</tr>
<tr>
<td>1b) Aluminium oxide and sodium hydroxide</td>
<td>14%</td>
<td>86%</td>
<td>0%</td>
</tr>
<tr>
<td>1c) Sulphuric acid and potassium iodide</td>
<td>0%</td>
<td>95%</td>
<td>5%</td>
</tr>
<tr>
<td>1d) Ethane, methane and oxygen</td>
<td>0%</td>
<td>71%</td>
<td>29%</td>
</tr>
<tr>
<td>1e) Carbon monoxide, methane, hydrogen and oxygen</td>
<td>0%</td>
<td>62%</td>
<td>38%</td>
</tr>
</tbody>
</table>

It is clear from the table that students have problems on predicting the products of the reaction. For example Freddy Mudzingwa failed to predict the products for the reaction between copper and nitric acid, he wrote it as:

$$3\text{NO}_3^- + \text{Cu} \rightarrow \text{Cu (NO}_3^+) + \text{NO}$$

Instead of $8\text{HNO}_3 + 3\text{Cu} \rightarrow 3\text{Cu (NO}_3^+) + 4\text{H}_2 + 2\text{NO}$.
Only 14% of the students managed to predict the product for the reaction between aluminium oxide and sodium hydroxide. For instance, James Tongai wrote it as:

\[ \text{Al}_2\text{O}_3 + \text{NaOH} \rightarrow [\text{Al(OH)}_2]^{3+}. \]

Instead of \( \text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl(OH)}_4. \)

Most of the students also failed to predict the products of the reaction of concentrated sulphuric acid and potassium iodide. Brian Chikumba wrote it as:

\[ \text{H}_2\text{SO}_4 + \text{KI} \rightarrow \text{HI} + \text{KHSO}_4 \]

Instead of \( 5\text{H}_2\text{SO}_4 + 8\text{KI} \rightarrow \text{H}_2\text{S} + \text{I}_2 + 4\text{K}_2\text{SO}_4 + 4\text{H}_2\text{O}. \)

From the results it is clear that students failed to predict the products of the reaction four between methane, ethane and oxygen. Oswald wrote it as:

\[ \text{C}_x\text{H}_y + (x+y/4) \text{O}_2 \rightarrow x\text{CO}_2 + y/2\text{H}_2\text{O} \]

Instead of \( \text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \) and

\[ \text{C}_2\text{H}_6 + 7/2\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O} \]

The same percentage of students did the same for the reaction on (1e) which was occurring between carbon monoxide, hydrogen, methane and oxygen. Doctor Chinouya wrote it as:

\[ \text{CO} + \text{CH}_4 + \text{H}_2 + \text{O}_2 \rightarrow \]

Instead of \( 2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2. \)

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \) and

\[ \text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

4.1.3 Identification of state symbols

The study revealed that the bulk of students have problems on interpretation of the symbolic equation. Figure 5 below illustrates the percentage proportion of the students who participated in this study’s correct and incorrect responses to items that required them to give the state symbols. All the questions that required students to write a balanced chemical equation that
should consist of state symbols for both the reactants and products. Questions 1(a), (b) and (c) from written task 1 and questions 2(a), (b) and (c) from written task 2 required state symbols.

**Figure 4:** correct and incorrect percentage responses to identification of state symbols

It is shown from the Figure 5 above that the students who took part in the study encounter problems in interpreting state symbols of either reactants or products in a reaction equation. They were leaving out or not providing the state symbols when writing the balanced chemical equations. There is a greater percentage on questions 2(a), (b) and 2(c) of responses without state symbols indicating that they do not know the state at which the reactants exist at room conditions.

4.1.3 Molar ratios

The percentage of students’ correct response to item 2(c) that required students to understand the use of mole ratios in symbolic equation is lower than the percentage of incorrect responses (see Figure 6 below). For example, Tinodaishie makanga failed to solve the mole ratios for the reaction between Iron (II) ethanedioate and potassium manganate (VII) ions as 5 moles of Iron (II) ethanedioate reacts with 3 moles of manganate (VII) ions as shown below:

\[
3\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 5\text{Fe}^{2+} + 24\text{H}^+ \rightarrow 10\text{CO}_2 + 5\text{Fe}^{3+} + 3\text{Mn}^{2+} + 12\text{H}_2\text{O}
\]
Tinodaisho interpreted it as 2 moles of manganate ions react with 10 moles of Iron (II) ethanedioate. The correct mole ratio is shown on the equation above. It is clear from the results that the performance of students on this item is very low indicating that students have problems in relating ratios of reactants and products formed.

![Pie chart showing students' responses on the molar ratio in the reaction between iron (ii) ethanedioate and manganate (vii) ions.]

**Figure 5:** students responses on the molar ratio in the reaction between iron (ii) ethanedioate and manganate (vii) ions

4.1.4 4.1.5 Incorrect coefficients

Most students who participated in the study had problems in writing the correct coefficients in the writing of chemical equations on questions 1(a), 1(b) and 1(c). Figure 6 shows the percentages of correct and incorrect responses on the mentioned items.
Figure 6: Students incorrect and correct responses on writing coefficients in balanced equations

It can be seen from Figure 6 above that students have difficulties in writing correct coefficients when writing chemical equation,

4.2 Stoichiometry quantities and calculations

Items in written task 2 in appendix 11 and item 1(f) tested students’ understanding of empirical formula, molecular formula, molar volume and reacting masses. Figure 4.3 illustrate the percentages of students who answered the stoichiometry quantities and calculations correctly and incorrectly.
Figure 7: Students who answered the stoichiometry quantities and calculations correctly and incorrectly

It is clear on Figure 8 above that students’ performance is low in all the stoichiometric quantities and calculations questions. They were challenged mostly in answering questions on molar volume. Fraser and Servant (1987) observed that even university students, make a lot of mistakes in solving stoichiometric problems due to confusion between different chemical quantities. This is in agreement with the findings of this study where students faced challenges in calculating molar volumes of gases evolved.

4.3 Reasons behind students’ learning of stoichiometry concepts difficulties

Students often encounter problems when solving stoichiometry concepts for example, Santi Cazona failed to calculate the percentage composition of the mixture of ethane and methane with oxygen. He failed to write the equation for the reaction and this meant that he had failed to get the molar volumes of the gases in the mixture. Molar ratios again were a problem because a large number of students could not write a balanced chemical equation which in turn affected their calculations involving molar masses or molar volumes of gases. The research findings show that most students had difficulties in answering the stoichiometry concepts questions. This is due to the abstractness in nature of the stoichiometry concepts, for example the term mole is abstract in nature because it has diverse meanings attributed to it. In the task based
discussions, the students also pointed out that student’ difficulties in answering stoichiometry quantities and calculations originated from their limitations in the mathematics knowledge needed to solve such problems. For example, Zimbabwe School Examination Council reports, 2010 November paper one which shows that students scores low marks because they could not tackle those questions which involved numerical calculations and writing of balanced equations. This is in agreement with findings from students’ responses in task based discussions. The students also pointed out that they could not relate the molar volumes of gases produced with the number of moles of reactants that combines chemically. The results converged with the findings from other studies like by Mitchell and Gunstone (1984). From the task based discussions students pointed out that they understand better when they are given presentations and by doing that they will be in charge of their learning.

4.4 Chapter summary

The chapter presented and discussed the results that were drawn from the analysis of data in chapter three. The findings of the study revealed that students encounter so many challenges in stoichiometry. Students who participated in the study were failing to write down chemical symbols and chemical formulae and also they failed write balanced equations. This is shown by their failure to answer more complex questions in stoichiometry such as calculations of reacting volumes. This is due to the fact that the students have very weak understanding of other topics related to stoichiometry such as the particulate nature of matter and chemical bonding. The next chapter deals with summary of findings, conclusions and recommendations.
5.1 Introduction

This chapter focuses on the summary of the study, conclusions and recommendations. It is also made up of three parts (1) summary of the study (2) recommendations (3) conclusions and any other relevant material that was used in the study. The chapter ends up with a chapter summary.

5.2 Summary of findings

This study sought to establish how students conceptualise stoichiometry concepts taught at advanced level. It also sought to identify how students’ understandings of these concepts compare with the received chemistry explanations and to identify sources of the gaps between students’ conception and received chemistry explanations. It has been shown from the literature by many researchers that many students encounter difficulties in comprehending stoichiometry concepts taught at advanced level. The data was collected using two tasks or tests. In written task one student was to write balanced chemical equations, write correct formulas of reactants and products and to predict products of chemical equations. I found out that students had problems in writing balanced equations; they could not predict products of chemical equations. For example, they could not give the products of the reaction of copper and nitric acid which are hydrogen, copper nitrate and nitrogen monoxide and they also failed to write formulas of reactants and products.

In written task two students had difficulties in showing correct interpretation of the mole ratios and had challenges also on calculating the molar mass. The calculation of molar volume was done fairly by most students.

5.3 Conclusion

In conclusion, the researcher found out that many students have difficulties in understanding stoichiometry concepts because they have shown lack of understanding of basic concepts. Basing on the research results most of the students did not show a clear understanding of basic
stoichiometry concepts such as writing of balanced chemical equations, use of mole ratios, prediction of products and writing of formulas of reactants and products. The difficulties and alternative conceptions that are shown in the literature of other studies also exist in this study.

5.4 Recommendations

The Ministry of Primary and Secondary Education (MPSE) through different schools should hold workshops to conscientize teachers on the alternative conceptions that the students have on stoichiometry concepts in such a way that they will adjust their instructional methods so that the held misconceptions will be overcome. Teachers should adopt the instructional methodologies that help overcome the held alternative conceptions and promote the scientific conceptions by following the steps (Olenick, 2008).

Teachers should know that alternative conceptions do exist and to probe for students’ alternative conceptions through demonstrations and questions.

Teachers should ask students to clarify their understanding and beliefs and to provide contradictions to students’ alternative conceptions through questions, implications and demonstrations and to foster the replacement of alternative conceptions with new concepts through questions and thought experiments.

Teachers should help students to learn how to write balanced chemical equations and to write formulas of substances. They should encourage group discussions on the stoichiometry topic. In the teaching and learning process teachers should use the learner centred approach.

5.5 Chapter summary

The chapter looked at the summary of findings, recommendations and conclusions of the students difficulties in understanding stoichiometry. The objectives of the study were met and the research questions were also answered from the findings. This marks the end of the study.
REFERENCES


Schmidt H.-J. & Jignéus C., (2003), Students’ strategies in solving algorithmic stoichiometry problems, Chemistry Education: Research and Practice, 4, 305-31

Smoot R. C., Price J. and Smith R. G., (1987), Chemistry: a modern course, Columbus, OH, Merrill


APPENDICES

Appendix 1: list of participating students

Mason Ndoro
Power M, Sithole
Oswald Maphosa
Kim Gororo
Fadzai Moyo
Wigan Spurs
Joseph Dick
Fredrick Stones
Taylor Rutsvara
Doink Cheso
Santi Cazona Maponga
Bolly Bhebhe
Nhaimoinesu Manyumbu
Brian Chikumba
Tinodaisho Makanya
Masunze Denzel
Orenthra Wrythm
James Tongai
Swiss Punde
Freddy Mudzingwa
Doctor Chinouya
Appendix 2: BUSE introductory letter

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

P Bag 1020,
Bindura,
Zimbabwe
Tel: 0263 0775 184 200
Email: vmpofu@buse.ac.zw

BINDURA UNIVERSITY OF SCIENCE EDUCATION

21 July, 2016

TO WHOM IT MAY Concern

RE: RESEARCH INTRODUCTION LETTER: DZINGIRAI PHILLOMINA
REGISTRATION NUMBER: B1441422

The above mater refers.

Ms. Dzingirai Phillomina is a Master of Science Education (Chemistry) bona fide student of
Bindura University of Science Education in the Faculty of Science Education.

He wishes to undertake research entitled: "Advanced Level Students' Understanding of
stoichiometry: Insights from Fife High School". This research is done in partial fulfilment
of the degree programme of the Masters of Science Education-Chemistry of Bindura
University.

On behalf of the Faculty of Science Education and Bindura University of Science Education,
the Department of Science and Mathematics Education, therefore, is kindly requesting you to
permit the above mentioned student to carry out her research in your institution(s).

Your co-operation and assistance is greatly appreciated.

Kind regards,

[Signature]

Dr. V. Mpofu (PhD-Wits, South Africa)
Chairperson, Faculty Projects Committee

22 Jul 2016
P Bag 1020
Bindura
Appendix 3: Application letter for research authority

House Number 1190
Adelaide Park
Senga
Gweru
28 August 2016

The secretary
Ministry of Primary and Secondary Education
Post Office Box CY121
Causeway
Harare

Dear Sir/Madam

RE: REQUEST TO CONDUCT RESEARCH AT FIFE HIGH SCHOOL

I am seeking permission to conduct a research titled Students difficulties in understanding stoichiometry concepts taught at advanced level: Insights from Fife High School in the Gweru district of Midlands Province in Zimbabwe.

Purpose: The purpose of the study is to establish how students conceptualise stoichiometry concepts taught at advanced level.

Procedures and duration: I wish to conduct this study with the students in Upper six doing chemistry. The participation of these students in this study is on voluntary basis with parental consent. The participants will respond to questions in two sets of written work as class
exercises. These responses form part of data generated which will be analysed by marking and content examination for in/correctness of responses. For each set of questions this analysis will be followed up by field noted task based discussions.

**Risks, discomforts or injury:** There are no potentially harmful risks related to participating in this study. Though no risks of any injury is envisioned as consequence of participating in this study, in the event of any direct injury resulting from your participation in this study contact the researcher at 0782886803

**Benefits, compensation and additional costs:** The students will not receive any financial or material benefits or any other compensation for participating in this study. This research is conducted on partial fulfilment of the Master of Science Education certificate requirements at Bindura University of science education. It is important to note that any costs related to participation in the study are met by the researcher. Participation in this study has no financial cost to students. Any costs related to participation are borne by the study and are not a responsibility of the participant. Though no direct benefit from this study to the participants is promised, you may gain individual understanding of the concepts of stoichiometry. This gives a good foundation for the subsequent study of chemistry studies in this level and at higher levels.

**Confidentiality:** All data and information generated in this study will be kept confidential. The participating school and students will be identified by pseudonyms in place of real names unless otherwise they feel so and give their consent. The researcher will keep the data material in a protected place. Only the researchers will have access to these and they will be destroyed by burning them.

**Voluntary participation:** Participation in this study is voluntary. Students may choose not to participate in this study. Those who would have agreed to participate may choose to withdraw at any time without any consequences. Participant’s image(s), if it appears anywhere, will be blurred so that the participant will not be visually recognised. Students can only participate in this study with full parental consent.
**Additional information:** For any further information regarding his/her rights as a research participant, he/she may contact: Dr. V. Mpofu via email at vmpofu@buse.ac.zw or cell 0775 184 200

**Conclusion:** I am prepared to answer any question on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have any concerns or questions about the conduct of this program of research study (project) you may contact me at location stated above.

**Authorisation:** By signing this letter, you are authorising this research to be conducted in Fife High School. Alternatively you can give a written reply to the researcher.

Yours sincerely

Dzingirai Phillomina

Reg number: B1441422

Cell 0782 886 803,email:dzingiraip@gmail.com
Appendix 4: MPSE authority letter

All communications should be addressed to "The Secretary for Primary and Secondary Education"
Telephone: 734051/59 and 734071
Telegraphic address: "EDUCATION"
Fax: 734075

Reference: C/426/3 Midlands
Ministry of Primary and Secondary Education
P.O Box CY 121
Causeway
Harare
12 September 2016

Dzingiral Philomina
House Number 1190
Adelaide Park
Senga
Gweru

RE: PERMISSION TO CARRY OUT RESEARCH IN MIDLANDS PROVINCE:
GWERU DISTRICT: FLETCHER HIGH SCHOOL

Reference is made to your application to carry out a research in the above mentioned schools in Midlands Province on the research title:

“ADVANCED LEVEL STUDENTS UNDERSTANDING OF STOICHIOMETRY:
INSIGHTS FROM FLETCHER HIGH SCHOOL”

Permission is hereby granted. However, you are required to liaise with the Provincial Education Director Midlands Province, who is responsible for the schools which you want to involve in your research.

You are required to provide a copy of your final report to the Secretary for Primary and Secondary Education by December 2016.

E. Chinyowa
Acting Director: Policy Planning, Research and Development
For: SECRETARY FOR PRIMARY AND SECONDARY EDUCATION

cc: Midlands Province
Appendix 5: Provincial authority letter

APPLICATION FOR PERMISSION TO CARRY OUT AN EDUCATIONAL RESEARCH IN SELECTED SCHOOLS IN MIDLANDS PROVINCE

Permission to carry out a Research on:-

ADVANCED LEVEL STUDENTS UNDERSTANDING OF SCIENCE IN SCHOOLS

In the Midlands Province has been granted on these conditions.

1. That in carrying out this you do not disturb the learning and teaching programmes in schools.
2. That you avail the Ministry of Primary and Secondary Education with a copy of your research findings.
3. That this permission can be withdrawn at anytime by the Provincial Education Director or by any higher officer.

The Education Director wishes you success in your research work and in your University College studies.

Education Officer (Professional Administration And Legal Services)
PFOR PROVINCIAL EDUCATION DIRECTOR: MIDLANDS
Appendix 6: District authority letter

Ministry of Primary and Secondary Education
P.O Box 737
GWERU
12 SEP 2016

Mr/Mrs/Miss: DZEIGAII PHILLIMWA

Dear Sir/Madam

APPLICATION FOR PERMISSION TO CARRY OUT AN EDUCATIONAL RESEARCH IN SELECTED SCHOOLS IN MIDLANDS PROVINCE

Permission to carry out a Research on:-

ADVANCED LEVEL STUDENTS UNDER STANDARDS RE
GEOMETRY INSIGHTS FROM CLETUNO HIGH

In the Midlands Province has been granted on these conditions.

1. That in carrying out this you do not disturb the learning and teaching programmes in schools.
2. That you avail the Ministry of Primary and Secondary Education with a copy of your research findings.
3. That this permission can be withdrawn at anytime by the Provincial Education Director or by any higher officer.

The Education Director wishes you success in your research work and in your University College studies.

Education Officer (Professional Administration And Legal Services)
PFOR PROVINCIAL EDUCATION DIRECTOR: MIDLANDS
Appendix 7: School authority letter

House Number 1190
Adelaide Park
Senga
Gweru
28 August 2016

The Head
Fletcher High School
Private Bag 9054
Gweru

Dear Sir/Madam

RE: REQUEST TO CONDUCT RESEARCH AT FIFE HIGH SCHOOL

I am seeking permission to conduct a research titled Students’ difficulties in understanding stoichiometry concepts taught at advanced level: Insights from Fife High School in the Gweru district of Midlands Province in Zimbabwe.

Purpose: The purpose of the study is to establish how students conceptualise stoichiometry concepts taught at advanced level.

Procedures and duration: I wish to conduct this study with the students in Upper six doing chemistry. The participation of these students in this study is on voluntary basis with parental consent. The participants will respond to questions in two sets of written work as class exercises. These responses form part of data generated which will be analysed by marking and content examination for in/incorrectness of responses. For each set of questions this analysis will be followed up by field noted task based discussions.

Risks, discomforts or injury: There are no potentially harmful risks related to participating in this study. Though no risks of any injury is envisioned as consequence of participating in this study, in the event of any direct injury resulting from your participation in this study contact the researcher at 0782888803.

Benefits, compensation and additional costs: the students will not receive any financial or material benefits or any other compensation for participating in this study. This research is conducted on partial fulfilment of the master of science education certificate requirements at Bindura University of science education. It is important to note that any costs related to participation in the study are met by the researcher. Participation in this study has no financial cost to students. Any costs related to participation are borne by the study and are not a responsibility of the participant. Though no direct benefit from this study to the participants is promised, you may gain individual understanding of the...
concepts of stoichiometry. This gives a good foundation for the subsequent study of chemistry studies in this level and at higher levels.

Confidentiality: All data and information generated in this study will be kept confidential. The participating school and students will be identified by pseudonyms in place of real names unless otherwise they feel so and give their consent. The researcher will keep the data material in a protected place. Only the researchers will have access to these and they will be destroyed by burning them.

Voluntary participation: Participation in this study is voluntary. Students may choose not to participate in this study. Those who would have agreed to participate may choose to withdraw at any time without any consequences. Participant’s image(s), if it appears anywhere, will be blurred so that the participant will not be visually recognised. Students can only participate in this study with full parental consent.

Additional information: For any further information regarding his/her rights as a research participant, he/she may contact Dr. V. Mpofu via email at vmpofu@bute.ac.zw or cell 0775 184 200.

Conclusion: I am prepared to answer any question on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have any concerns or questions about the conduct of this program of research study (project) you may contact me at location stated above.

Authorisation: By signing this letter, you are authorising this research to be conducted in Fife High School. Alternatively you can give a written reply to the researcher.

Yours sincerely

Dzingirai Philiomina

Reg number: B1441422

Cell 0782 886 803, email: dzingirai@gmail.com
Appendix 8: Student consent form

: STUDENTS’ CONSENT FORM

I agree to participate in the research study titled: Students difficulties in understanding stoichiometry at advanced level: Insights from Fife High school to be conducted at Fife High School.

I further agree to video recording during the study. (Mark either “Yes” or “No”)

I agree to having his/her video recorded

I agree to having his/her participation in study

Name of Research Participant

Signature

Researcher Name

Designation

Date

Signature
Appendix 9: Parent/guardian consent form

: PARENT / GUARDIANS’ CONSENT FORM

I, ..............................................................................................................being the parent or guardian of ..................................................do hereby authorise his/her participation in this research study titled: Students difficulties in understanding stoichiometry concepts taught at advanced level: Insights from Fife High school at Fife High School.

I further agree to video recording during the study. (Mark either “Yes” or “No”)

I agree to having his/her video recorded

[ ] Yes
[ ] No

I agree to having his/her participation in study

[ ] Yes
[ ] No

Name of Research Participant

______________________________

Signature

______________________________

Researcher Name

______________________________

Signature

______________________________

Designation

______________________________

Date
Appendix 10: Written task 1

Appendix 8: Written task 1

Section A: Introduction

This task card requires students to construct balanced chemical equations with state symbols and correct formula of both the reactants and products.

Section B: Background

Name of participant: Daniel Carcella

Venue: Senior Chemistry Lab

Date: 15/09/16

Duration:

Section C: Items or questions to be answered.

1. Write correct and balanced chemical equations for the chemical observations shown.

(a) Nitric acid oxidises copper metal to copper (II) nitrate and nitrogen monoxide is given off.

(b) Aluminium oxide gives sodium aluminate with sodium hydroxide solution.

(c) When concentrated sulphuric acid is added to solid potassium iodide, a purple vapour is seen and hydrogen sulphide is given off.

(d) 24 cm$^3$ of a mixture of methane and ethane were exploded with 90 cm$^3$ of oxygen. After cooling to room temperature the volume of gas was noted. It was found to decrease by 32 cm$^3$ when treated with potassium hydroxide solution. Calculate the composition of the mixture.

(e) 32 cm$^3$ of a mixture of carbon monoxide, methane, and hydrogen were mixed with 50 cm$^3$ of oxygen and exploded. After cooling to room temperature, the volume was noted. It was reduced by 22 cm$^3$ when exposed to potassium hydroxide solution, leaving 16 cm$^3$ of excess oxygen. Calculate the composition of the mixture.

(f) An organic acid was shown on analysis to contain 49% carbon, 6.7% hydrogen, 53% nitrogen, and 3% oxygen. If the relative molecular mass of the acid was 60, identify the acid.

Section D: Closing remarks

I would like to thank all the students for taking part in the generation of data.
Appendix 11: Written task 2

Section A: Introduction

In this section students are asked to show the correct interpretation of the mole ratio, correct formula of reactants and products and perform calculations.

Section B: Background

Name of participant: Brian Chukumba

Venue: Chemistry Lab

Date: 16/09/16

Duration: 35 minutes

No of participants

Section C: Items to be answered

2) Perform calculations on the information provided on items (a) to (c).

a) What volume of 0.10 mol dm$^{-3}$ aqueous silver nitrate completely reacts with 25.00 cm$^3$ of 0.20 mol dm$^{-3}$ barium chloride?

b) A 0.10g sample of a monobasic acid requires 10.00 cm$^3$ of 0.10 mol dm$^{-3}$ sodium hydroxide for complete reaction. What is the relative molecular mass of the acid?

c) A 1.50g sample of anhydrous iron (II) ethanedioate was dissolved in 100 cm$^3$ of water. 100 cm$^3$ sample of the solution required 15.00 cm$^3$ of potassium manganate (VII) for complete reaction titration. Use the following half-equations to write the overall equation for the oxidation of iron (II) ethanedioate by potassium manganate aqueous.

\[ \text{Fe}^{2+} + e^- \rightarrow \text{Fe}^{3+} \]

\[ \text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} \]

Section D: Closing remarks

I would want to thank all those who participated in the writing of the exercise.
Appendix 12: Task based discussion guide 1

Task Based Discussion guide 1

This section focuses on the problems faced by students in the writing of written task 1.

State and explain the reasons behind each problem area.

- Leaving out state symbols when writing an equation.
- Writing an unbalanced chemical equation.
- Leaving out other products as in the reaction of copper and nitric acid.
- On items (d) and (e) combustion of the gaseous mixture equations were not given and calculations that involved the composition of the mixture were not done correctly.

This discussion will be followed by the writing of written task 2.
Appendix 13 Task based discussion guide 2

This guide aims at discussing the areas that were a problem to the students.

State and explain the reasons behind the problem areas that were identified from your responses.

- Failing to calculate the volume of silver nitrate that reacted with barium chloride.
- Numerical answers were not accompanied with units as in items 2 (b).
- Failing to write balanced chemical equations before carrying out calculations.
- Failing to write the formula of reactants or products, for example, Iron (II)ethanedioate.