INFLUENCE OF PROCESS ORIENTED GUIDED INQUIRY LEARNING (POGIL) ON SCIENCE FOUNDATION STUDENTS` ACHIEVEMENTS IN STOICHIOMETRY PROBLEMS AT THE UNIVERSITY OF NAMIBIA

By

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ABSTRACT

The study investigated the influence of Process Oriented Guided Inquiry Learning Approach (POGIL) on Science Foundation students' achievements in stoichiometry versus traditional lecture centered pedagogy. Two intact science foundation class groups at the University of Namibia were used as a case study. A quasi-experimental non-randomized pre and posttests control group design was used to investigate the achievement in stoichiometry. Data on student achievements were collected and analyzed using descriptive statistics and Analysis of Covariance (ANCOVA). The ANCOVA results showed that there was a significant statistical difference in achievements when comparing the adjusted mean score (54.5%) obtained by the control group and the adjusted mean score (60.5%) obtained by students in the POGIL group; (F (1,75) = 17.990, $p < 0.05$). The POGIL group also showed the highest average improvement (65%) on questions related to reaction stoichiometry and limiting reagents, whereas the control group recorded improvements of about 53% in the same section. The results from the analysis of student's test solutions revealed that the POGIL group students were able to give concrete reasons for their answers that they had obtained through numerical calculations or multiple choices and demonstrated enhanced understanding of linking various stoichiometry concepts.

DECLARATION

I declare that **INFLUENCE OF PROCESS ORIENTED GUIDED INQUIRY LEARNING (POGIL) ON SCIENCE FOUNDATION STUDENTS` ACHIEVEMENTS IN STOICHIOMETRY PROBLEMS AT THE UNIVERSITY OF NAMIBIA** is my own work and that sources that I have used or quoted are indicated and acknowledged by means of complete references.

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SIGNATURE	DATE
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KEY TERMS

Foundation Chemistry, Stoichiometry, Science Foundation, POGIL, Conceptual understanding, Constructivist perspectives

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CHAPTER 1

INTRODUCTION

1.1 Background to the study

The University of Namibia is one of the few recognized institutions of high learning in Namibia, among others such as the Polytechnic of Namibia and International University of Management (IUM). The University of Namibia was established in August 1992 by the Parliamentary Act No.18 of 1992. Like many other tertiary institutions, the University of Namibia has been facing numerous challenges. The University faces significant challenges including responding to the needs of disadvantaged Namibians, often living in rural areas and far outlying regions and attempting to redress the inequality of the past (Hodin, 2005).

In an attempt to increase the number of graduates in science and science related fields, the University of Namibia through funding from the Ford Foundation Pathway Programme established a Science Foundation Programme at its Oshakati Campus in 2005 (Kapenda and Ngololo, 2009). The overall goal of establishing a foundation year at the University of Namibia is to increase the quantity and quality of qualified science and technology graduates for Namibia' s growing economy (University of Namibia 2005). Since the Science Foundation Programme's institutionalization in 2004 and inception in 2005, the programme's annual intake has increased from 60 students in 2005 to 146 students in 2011. This Study explores the avenues of how best to prepare the Science Foundation Programme students for entry into their first year of the university. The emphasis is placed on Chemistry, because the author is currently involved in the teaching of Chemistry at foundation level and therefore has realized the need to explore various student–centered activities that actively engage students in their studies and at the same time

enhance conceptual understanding of Chemistry. The main focus is to assess the influence of Process Oriented Guided Inquiry Learning (POGIL) on the current conceptions of Science Foundation students on one of the fundamental topic in Chemistry which is Chemical Stoichiometry.

1.1.1 Foundation Programmes

The concept of University Foundation Programme is fairly new in Namibia. However, the available literature argues for the existence of various foundation programmes in the neighboring country South Africa, as well as in other continents such as Europe and Asia (Kapenda and Ngololo, 2007). A university foundation programmme can be a one or two years preparatory course targeting potential students who lack training or language skills for entry requirements in a particular field of study. Foundation Programme can be operationary defined as a special programme for students whose prior learning has been adversely affected by educational or social inequalities (Kloot, Case and Marshall, 2008). There are several studies done in South Africa, pertaining to the impact of foundation programmes in education sector and particularly in the area of natural sciences (Mundalam, 2006; Grayson, 1996, 1997b). According to the International Panel (2004), the Foundation Programme in South Africa may take a number of modes such as a fully-fledged foundation year after that successful students are then allowed to register for their preferred fields of studies. Some foundation programmes are fully merged within a particular study course such that upon completion, successful students are allowed to enter the second year of their study programmmes. Various South African universities such as University of Natal, University of Limpopo and the University of Pretoria run their foundation programmes for one full academic year (Mundalam, 2006).

1.1.2 The Science Foundation Programme at the University of Namibia

The Science Foundation Programme is a one year programme that is offered by the University of Namibia at its Oshakati Campus. The programme accepts normally learners from rural schools whose grade 12 results are not good enough to be admitted into the main stream of the university courses. Students are admitted on the programme based on the combination of their grade 12 results and the foundation entrance test. The foundation year consists of 5 compulsory modules which are English Foundation, Foundation Chemistry, Foundation Physics, Foundation Biology and Foundation Mathematics. During the course of the year students get engaged in a number of teaching and learning activities. The Chemistry course which is the main focus of this study consists of five hours of lesson per week. Two out of five hours are reserved for practical activities whereas the remaining three hours are theory based. The content for Chemistry Foundation covers some topic areas from grade 12 Physical Science Syllabus and first year university chemistry curriculum.

The Philosophical Foundations of the Science Foundation Programme are based on a holistic approach to teaching and learning. The underlying pedagogical goal is to prepare potential Students for a lifelong academic achievement as well as personal social fulfilment. It is well documented that many tertiary Institutions' Curriculums are more academic oriented (Grayson 1997). This implies that these crucial documents that make up the teaching and learning framework do not explicitly put into consideration the underlying pedagogical skills that are needed in facilitating the teaching and learning of Specific Subject Content. Resent Science Education researchers have expressed the importance of acquiring Specific Subject Content Knowledge by teachers and University lecturers. Specific Subject Content Knowledge refers to

various pedagogical skills that lecturers may need in the process of teaching and learning of particular subject knowledge such as Stoichiometry (Okanlawon, 2010).

The Curriculum content of the Science Foundation Programme is deliberately designed such that the content coverage permits the inclusion of vital Pedagogical Strategies such as Study Skills, Confidence building, Communication of understandings and Self-reliance. Science Foundation students are expected to think and reason logically, such that they would be able to explain what they have learnt to their peers. These Skills are not only needed for academic achievement but also for lifelong progress in real life situations.

The Aims and Objectives of the Foundation Chemistry course are as follow: Hodin (2005)

The aim is to:

- *provide a well-designed course to develop critical understanding of the underlying concepts and theories in chemistry.*
- *develop abilities and skills that are relevant and useful to a chemistry course.*
- *develop attitudes such as concern for accuracy and precision, objectivity and enquiry.*
- *be aware of the environment and how chemistry can be both helpful and harmful to all living things and the environment.*
- *be suitably prepared to follow a degree course in sciences at the University of Namibia.*
- *be able to communicate their understandings of knowledge to others.*
- *be able to think and reason logically.*
- *apply what they have learnt in real life situation.*
- *objectively carry out scientific observation and investigation*

1.2 Statement of the problem

Research on students' problems on stoichiometry have provided valuable information with respect to secondary school as well as college students' misconceptions and problem solving strategies in stoichiometry (Schmidt, 1997; BouJaude and Barakat, 2000). However, we do not know whether these long identified problems areas have brought about improvement in the understanding of this fundamental topic in chemistry particularly at secondary school level and bridging programmes that prepare students for further studies in chemistry at the university level.

A recent research study by Potgieter and Davidowitz (2011) revealed that first year Chemistry students at selected South African universities were experiencing problems with basic stoichiometry concepts such as stoichiometric ratios of chemical formulas and balanced chemical equations. Studies involving conceptual changes methods show that alternative conceptions are relatively problematic to change and those current teaching techniques are still resulting in alternative conceptions (Talanquer, 2006; Tastan, Yalcinkaya and Boz, 2008). Therefore, this study explored on a teaching- learning model that aims to enhance foundation students' existing conceptions of basic scientific principles that constitute a fundamental component of Chemistry called Chemical Stoichiometry. Basic Stoichiometry concepts were identified as the basis of this research because of abundant literature reports on its importance and student difficulties regarding these concepts in chemistry education. Moreover, such reports of related research in other contexts, will also afford an opportunity to tap out relevant empirical evidences that may constitute a theoretical framework of this particular study.

1.3 Research Questions

This study will investigate the following research questions

1. What is the influence of Process Oriented Guided Inquiry Learning instructions on achievements of Science Foundation students in stoichiometry problems?

2. Does the use of POGIL approach enhance conceptual understanding of Stoichiometry concepts in chemistry foundation classes?
3. Does the use of POGIL approach facilitate the learning of stoichiometry concepts in chemistry foundation classes

Hypotheses:

The following hypotheses stated analyzed at 0.05 probability significant level were used to answer question 1 of this research study.

H_0: There is no statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

H_1: There is a statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

1.4 Research purpose

Overall, this study intends to determine the impact of the use of POGIL instructional model on the achievements of Science Foundation students in Stoichiometry. This main purpose can be broken down into the following specific objectives.

- To facilitate and guide Science Foundation students on the use of POGIL materials when learning Stoichiometry.
- To investigate the impact of POGIL instructions on Science Foundation students' achievements in Stoichiometry versus traditional teacher – centered pedagogy.
- To analyze in detail students' stoichiometry test solutions for conceptual understanding.

1.5 Significance of the study

This research study extends on previous studies, in the sense that it uses a special group of subjects from a relatively newly established bridging programme at the University of Namibia, as compared to previous studies that have focused mostly on secondary school students and first year college or university students. The study will enable the author who is currently teaching Chemistry Foundation, to plan and devise student based activities that are relevant in fostering scientific skills such as critical thinking and conceptual understanding.

This effort may help teaching staff at the Science Foundation Programme to devise teaching and learning mechanisms that are suitable for these students. Secondly, it is anticipated that the outcomes of this particular study may put Science Foundation lecturers in a better position of assisting students to get actively involved in the construction of their own scientific knowledge. According to Von Glasersfeld, (1996) "one can hope to induce changes in students' way of

thinking only if one has some inkling as to their domains of experience, concepts and the conceptual relations they possess at that time".

Moreover the demand for skilled science professionals is escalating every year in Namibia, therefore government officials and policy administrators may need to be provided with empirical evidence on ways of increasing the number of quality graduates in sciences and technological fields. In conclusion, the knowledge on how students construct and generate meaning of concepts and process will according to (Gravett, 2004) go a long way in "getting ordinary students enrolled at higher education to engage in higher - order learning processes that the more academic student tends to engage spontaneously"

1.6 Operational Definitions of Terms

Achievement test: Is a test designed to measure conceptual understanding in Stoichiometry concepts learnt in this particular study.

Constructivist perspective: Is a learning theory that is based on the idea that students actively construct their own meanings in unique ways as they interact with their learning environment and different experiences (Killoran, 2003).

Conceptual understanding: Students' ability to apply the learned scientific concepts to solve different stoichiometry related problems.

Process Oriented Guided Inquiry Learning: A pedagogical philosophy which is based on guided inquiry learning, in which students in small groups get engaged in carefully designed

learning materials that guide students to generate and construct their knowledge (Moog and Spencer, 2008).

Science Foundation: Is a one year pre-degree programme at the University of Namibia that is designed to identify and prepare potential students whose' grade 12 results are not good enough to get a direct admission to tertiary studies. The programme prepares students for various science related careers.

Stoichiometry: Stoichiometry is a section of Chemistry that involves the use of quantitative relationships between reactants and/or products in a chemical reaction in order to determine desired quantitative data.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Teaching Stoichiometry calculations is viewed by Chemistry instructors as a difficult task Schmidt (1994). Many researchers have investigated the nature of factors affecting students understanding of concepts related to Stoichiometry while others have studied students' problem-solving strategies in Stoichiometry (Boujaude and Barakat, 2000). Difficulties with conceptual understanding of Chemistry and Stoichiometry in particular are aggravated in Namibia, due to the disadvantages in the school situations such as the shortage of laboratory facilities and other relevant teaching aids for the majority of the population.

This chapter begins with the theoretical framework for this study, followed by a review of research findings on teaching and learning of Chemical Stoichiometry. Finally, the chapter is concluded with a review of research findings on the effectiveness of Process- Oriented Guided Inquiry Learning (POGIL).

2.1 Theoretical framework

The theoretical framework for this study is constructivist in nature and focuses on the following underlying principles; Constructivist Perspective, Inquiry Learning, Dynamic Skill Theory and the Learning Cycle.

2.1.1 Constructivist perspectives

This study is guided by the notion that learning is believed to occur through students actively constructing / generating their own meanings from different experiences to which they are exposed (Bodner, 1986). This idea is in accord with the fundamental views of epistemology

expressed by Piaget and is commonly known as the Constructivist Theory of learning (Liu and Matthews, 2005). Paget's constructivist has put into consideration various stages in which the natural mind and thought of a human being develops from birth to adulthood (Piaget, 1975). According to Piaget, the knowledge of a human being is not programmed in the brain like a computer programme but is being constructed and reconstructed during the growth period of a person. The development of individuals' mind and cognition is highly influenced by the environment and changes with contextual experiences (Piaget, 1980). Piaget has postulated that cognitive potentials and abilities are acquired and defined through major developmental stages. These stages as identified by Piaget are commonly known as *assimilation, accommodation and equilibration* (Piaget, 1977).

Assimilation is the process of creating associations and connections between newly acquired information and the existing knowledge. Piaget and Inhelder, in Bell- Gredler (1986) have stressed that assimilation should not be interpreted as a passive mode of acquiring new knowledge, but rather as a series of actions that recognize and filter the newly acquired information, so that they can be incorporated within various cognitive mental structures called schemata.

Accommodation is a complementary step of assimilation that involves the fitting and adapting of newly acquired information to the already existing schemata. During accommodation existing cognitive structures are readjusted and new schemata are created such that new ideas or events to which an individual is exposed to, can be fitted into these adjusted cognitive mental structures. New schemata are internalized and may constitute individual knowledge, but they remain prone to external changes which an individual may experience.

Equilibrium: Although new schemata are internalized during repetitive series of assimilation and accommodation an individual remains open to new contextual experiences as a person continues to interact with the environments that enhance survival and growth. Equilibrium as a dynamic state of cognitive growth continuously maintains and regulates the balance between internalized mental knowledge and external factors (Piaget in Bringuier, 1980).

2.1.2 Implications of constructivism theory in the teaching and learning context

According to Piaget's theory, individuals learn through interacting with their environment. Therefore, when students come to classes they do possess some pre- existing knowledge that they have picked up from past learning experiences through the process called assimilation (Bodner, 1986). In the teaching and learning context, the pre -knowledge of students is very essential because any new idea must be built from the existing one. The common aim of all Science educators is to help students learn science subjects such as Chemistry in the most appropriate way. Therefore, the more effective learning activities, such as POGIL should be adopted to help students acquire meaningful learning. These learning activities should help students to construct and organize their knowledge in a way that can direct them to use the required information accurately. The POGIL approach used in this particular study is adopted from constructivist perspectives, rooted from social constructivism. Social constructivism is a type of constructivist theory whereby individual learning takes place, because of learners' interaction within a group (Duffy and Jonassen, 1992). A POGIL learning activity engages students and promotes restructuring of information such that students develop understanding by employing the learning cycle through guided inquiry activities (Hanson, 2006).

2.1.3 Inquiry learning

Inquiry learning is defined as a systematic method of teaching by giving learners tasks that develop learners' thinking skills (Hanson, 2006). John Dewey, a well-known Philosopher of education at the beginning of the 20th century, was the first to criticize the fact that science education was not taught in a way to develop young scientific thinkers. Dewey proposed that science should be taught as a process and way of thinking – not as a subject with facts to be memorized (National Research Council, 2000). Inquiry-based learning is fundamental for the development of higher order thinking skills. According to Bloom's Taxonomy, the ability to analyze, synthesize and evaluate information or new understandings indicates a high level of thinking (Prince and Felder, 2006). Inquiry instructions are learner centered compared to direct teacher instruction strategies. Inquiry learning is characterized by an emphasis on problem solving, collaborative group work and critical thinking. Bybee (2004) describes inquiry features that can be essential in teaching scientific investigation as follow:

- Learners engage in scientific oriented questions.
- Learners give priority in responding to questions.
- Learners use evidence to develop an explanation.
- Learners connect their explanations to scientific knowledge.
- Learners communicate and justify their explanations.

There are three types of inquiry learning as described by Martin – Hansen (2002), namely: Open Inquiry, Guided Inquiry and Directed Inquiry (Structured Inquiry).

Table 2.1: Classroom inquiries and their variations

Open Inquiry	**Guided Inquiry**	**Directed Inquiry**
Learners pose questions to be investigated after being exposed to the problem.	Learners sharpen and clarify questions provided by a teacher or other materials.	Learners engage in questions provided in text books or by a teacher.
Learners plan and conduct investigations with minimum interference from the teacher.	Learners work with a teacher as a facilitator on how investigations will be carried out.	Experimental procedures are provided by the teacher.

Low (amount of support from the teacher) High

Interpretation of the table 2.1 shows that in Open Inquiry, the teacher has minimum control of the learners by allowing learners to contribute more. In Guided Inquiry both learners and the teacher have control of the learning situation. Guided Inquiry can often lead to open inquiry investigation and therefore can be used at the initial stage of developing skills of Open Inquiry investigation. Directed Inquiry is more teacher- centered as compared to other two types of inquiries and can be regarded as less effective method of promoting Scientific Inquiry. POGIL activities that are dealt with in this study are based on Guided Inquiry.

2.1.4 Dynamic skill theory

In 1980, Kurt Fischer a Professor of Education at Harvard Graduate School of Education introduced a comprehensive theory of human development that not only describes mechanisms of development, but also considers the impact of contextual and interpersonal factors on learning (Fischer, 1980; Fischer and Bidell, 2006). Fischer's theory is well known in cognitive

developmental science as dynamic skill theory. Dynamic skill theory specifies levels of development similar to that of Piaget, but indicates also that those emerging levels only signify the highest possible levels of achievement for any particular age group, without considering the dynamicity nature human cognition (Mascolo and Fischer, 2010). This means that in real life situations, humans show a range of cognition that is not static. Dynamic skill theory is based on the principle that human behavior is flexible and dynamic (Fischer and Rose, 2001). According to this theory many different factors (biological and contextual) influence performance of individuals and this makes human behaviors both complex and variable. When the relative variability was noted in human behavior, researchers such as (Fischer and Bidell, 2006) have identified factors that have a systematic effect on behavior and performance of a person under different contextual situations. Fischer and Bidell (2006) have expressed that one powerful source of variability in human behaviors and performance is contextual support.

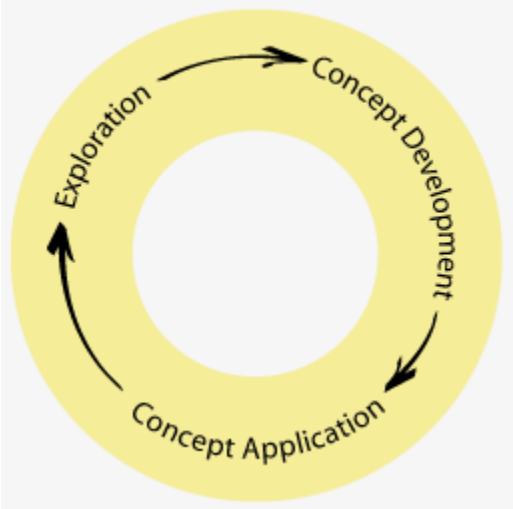
Contextual supports in educational setting may range from prompts, model, interactive study groups, cooperating with someone more advanced, just to mention a few. Through contextual supports a person may perform at a high level called optimum level. If there is no enough contextual supports a person's performance may reach up to a functional level, and that is the maximum functional level of an individual when there is less support. Chemistry concepts are often complex and abstract in nature hence it may require time and practice. Based on dynamic skill theory, one may deduce that educators should create supportive systems that allow students to reach optimum performance when engaged with abstract concepts such as stoichiometry.

POGIL activities used in this particular study are comprised of various support systems such as cooperative, inquiry thinking and models that may help students to operate at optimum levels of their thinking capacities.

2.1.5 The learning cycle

The learning cycle is a model of instructions based on a scientific inquiry. In the early 1960's, Robert Karplus and his colleagues proposed and used an instructional model based on the work of Piaget. This model would eventually be called the Learning Cycle (Lawson, 1995). This model encourages students to develop their own understanding of a scientific concept, explore and deepen that understanding and then apply the concept to new situations (Bybee 1997).

Figure 2.1: Major steps involved in the learning cycle (Adapted from Bybees, 1997).



Exploration

In the first phase, students in a group of three to four are tasked to examine a certain scientific concept or model and attempt to understand its meaning through open discussions and investigations (Sunal, 2007). The teacher will act as a facilitator by encouraging this open discussion through questioning and suggestions. During this phase students are formulating new

ideas and hypotheses about the concept or model under study. These newly formulated ideas and hypothesis are recorded such that they are tested later through experimentation or observation.

Concept development

During the second phase hypothesis and observations made during the exploration phase are being shared and validated by various group members through experimentation or argumentation. The facilitator may guide students by introducing more additional scientific concepts and alternative methods that are key to the phenomena under investigation (Clement, 2004). The facilitator may present extra written or audio-visual materials that may guide students to develop more concepts and relevant vocabulary about the model being studied.

Concept application

During this phase students are presented with a related problem which may require them to apply ideas and concepts which they formulated during the exploration and concept development phases (Sunal, 2007). At this stage students are left to work on their own with minimum assistance from the facilitator. During concept application, students may encounter unfamiliar phenomena or emerging concepts that may confront their initial observations. Therefore, the facilitator should take note of these concepts such that they become the starting point for the next exploration phase of the learning cycle (Clement, 2004). POGIL activities are the main focus of this study and were developed to follow a broadly defined learning cycle model.

2.2 Studies on teaching and learning of chemical stoichiometry.

2.2.1 Scientific background on chemical stoichiometry

Stoichiometry is one of the fundamental topics in the chemistry discipline. The term Stoichiometry comes from the Greek "stoicheion" (element) and "*metron*" (measure) Kolb (1978). Stoichiometry is generally defined in modern General Chemistry text books as "mass/mole relationships between reactants and products in a chemical reaction" Chang and Overby (2011.) Stoichiometry is regarded as one of the fundamental topics because attainment of high degree of proficiency in solving Stoichiometry problems is needed for dealing with equilibrium and acid-base problems (Evans, Leinhardt, Karabinos, and Yaron, 2006). Stoichiometry is crucial in calculating the amounts of materials that are needed in producing new chemicals in that, it helps to determine the desired amount of materials needed for production without unnecessary amount of waste (Eisenkraft, 2007). Stoichiometry has also played a key role in the evolution of Chemistry as a science, marking the difference between qualitative and quantitative chemistry. From these definitions, one probably can deduce that this branch of Chemistry mainly deals with quantitative relationships between reacting substances (reactants) and products of the reactions. Although, Stoichiometry definitions are more of quantitate in nature, it is essential for one to understand both quantitative and qualitative aspects of chemical reactions BouJaude and Barakat (2003). Despite the importance of Stoichiometry in understanding chemistry, research studies have shown that Stoichiometry calculations have always been difficult for students (Fach, de Boer and Parchmann, 2007; Evans, Yaron and Leinhardt, 2008; Chandrasegaran, Treagust, Waldrip and Chandrasegaran, 2009).

Stoichiometry, as a fundamental topic of Chemistry, requires concrete knowledge of quantitative relationships between substances being consumed or produced during chemical reactions

(Okanlawon, 2010). These quantitative relationships often, expressed in the form of ratios are technically defined by various balanced chemical equations that may represent the occurrence of individual chemical reactions. Typical problems that one may encounter when dealing with stoichiometry activities are:

Magnesium ribbon burnt in air to form a white powdery compound magnesium oxide. The balanced chemical equation is expressed below;

$2Mg\ (s) + O_{2\ (g)} \rightarrow 2MgO\ (s)$

(1) How much magnesium oxide (in grams) will be produced if 3.00 g of magnesium is burnt in the air?

(2) How much grams of magnesium and oxygen respectively are required to produce one kilogram of magnesium oxide?

(3) If 5 g of magnesium ribbon were burnt in 500 g of Oxygen gas. Determine the limiting reactant.

To solve these types of problems, a student must have a good understanding of Stoichiometry concepts and how they are interrelated. A student should be capable to construct and apply mathematical operations such as ratios and proportions or factor analysis method.

2.2.2 An outline of studies related to students' understanding of Stoichiometry.

The importance of Stoichiometry in Chemistry teaching is validated by the presence of various research reports regarding problems related to the teaching and learning of Stoichiometry and related concepts. Various researchers have approached this fundamental topic from different

angles of chemistry education. Some of the key research reports found in literatures have covered the following scenarios:

- Students and teachers' alternative conceptions as well as students' and teachers' difficulty in teaching and learning of Stoichiometry (Furio , Azcona and Guisasola, 2002).
- Several investigations have been carried out to identify the difficulties experienced by students using the mole concept in Stoichiometry calculations (Kolb, 1978; Case and Fraser 1999; Dahson and Coll, 2007).
- Students' ability to solve problems using algorithms without reasoning and processing skills, that demonstrate conceptual understanding has been widely documented in literature (Shcmidt, 1994; Huddel and Pillay, 1996; Niaz and Robinson, 1992; Boujaude and Barakat, 2000; Sanger, 2005; Papaphotis and Tsaparlis, 2008; Toth, and Sebestyen, 2009; Drummond and Selvaratnam, 2008; Selvaratnam and Mavuso, 2010; Selvaratnam (2011); Ochonogor (2012).
- Recent researchers have focused on Pedagogical Content Knowledge (PCK) of University professors and Chemistry teachers (Okanlawon, 2010; Padilla and Garritz, 2008).

2.2.3 Mathematical concepts and stoichiometry problem- solving.

Mathematical knowledge has been widely confirmed as a pillar that influences achievement in various fields of science such as Physics, Chemistry and Engineering. Several Chemical Education researchers have studied the relationship between Mathematics and Chemistry and reported that mathematics is a basic component to understanding Chemistry (Adeyeye, 1999;

Adesugba, 2006; Oluwatayo, 2011). The connection between Chemistry and Mathematics includes the use of multiple and related variables, ratios and proportions, graphs, logarithms and many others. Studies have shown that despite the relevance of Mathematics to understating Chemistry, many students have experienced difficulties mainly due to its mathematical requirement (Fensham and Lui, 2001; Chadrasegaran , Treagust, Waldrip and Chadrasegaran, 2009).

The most important part of the Chemistry Curriculum that requires a strong basis in Mathematics is in the study of the mole concept and Stoichiometry. It is generally believed that certain concepts such as mole, gas law, Stoichiometry and many others require knowledge of basic mathematical concepts. For example students are expected to master Basic Mathematics such as ratios and proportions before getting exposed to the mole concept. College Chemistry students report that Stoichiometry is both the most useful and best remembered concept from high school Chemistry studies. However, it is also the concept which is consistently named the hardest (Tai,Ward, and Sadler, 2006). One major contributory factor to facilitating Stoichiometry problem solving is the tendency for students to treat Stoichiometry problems like any other problem in Mathematics, with little display of their knowledge and understanding of the chemical principles involved (Chadrasegaran, Treagust, Waldrip and Chadrasegaran 2009). Fensham and Lui (2001) pointed out that students often get confused by equations used in Mathematics and those in Chemistry. This can be attributed to the fact that students may know well how to compute mathematical and chemical equations but the fundamental meanings of this equation are not well understood. Students' limited proficiency in the use of mathematical concepts, such as ratios and percentages in reaction Stoichiometry is another contributory factor (Bucat and Fensham, 1995). Some students think that the ratio of moles to atomic units is always

one-to-one ratio (Stave and Lumpe, 1995). It is also reported that some students have difficulties in recognizing the relationship between variables Dori and Hameiri, (2003). The implication of this report is much evident in chemistry practicals whereby students are required to relate and interpret experimental data. A Study by Adesugba (2006) showed that many secondary school students lack conceptual and mathematical skills for success in Chemistry and Stoichiometry in particular.

Methods for improving student understanding of this unit include a mole ratio flow chart and particulate representations of chemical reactions and Stoichiometric relationships (Sanger, 2005). Particulate representation has been found to be particularly useful in resolving students' confusion about superscripts and subscripts in chemical formulas (Treagust, Chittleborough and Mamiala, 2003; Marais and Combrinck, 2009).

Oluwatayo (2011) carried out a study on the effect of pre-exposure of students to basic mathematical concepts on their achievement in quantitative aspects of chemical reactions. Experimental data were collected and analyzed using means, standard deviation and t-test. Reported findings of this experimental research study revealed that the experimental group performed significantly better in the posttest as compared to the control group, suggesting that pre-exposure of students to basic mathematical concepts to a certain extent may facilitates better performance in quantitative aspects of chemical reactions.

Chadrasegaran, Treagust, Waldrip and Chadrasegaran, (2009) commented that although Mathematics is mainly concerned with operation on numbers, in Chemistry it should be stressed on operating physical quantities such as mass, amount of substance and volume just to mention a few. Although students' problems with handling mathematical relationships are widely acknowledged by Chemistry teachers, there is a limited reference to research in this area.

Therefore, educators really need to look up for metacognitive strategies that may enhance students to connect science concepts and mathematical computations. The importance of these mathematical concepts is stressed by Koch (1995) who emphasized that "*the ability to understand and use proportional reasoning is at the heart of stoichiometry*"

2.2.4 Reasoning and algorithmic strategies in stoichiometry problem solving

Common strategies that students use during problem solving in Chemistry as well as the relationship between conceptual and problem solving are well documented in the Science Education research literature for example, Gabel and Sherwood, 1984; Nakhleh, 1993; Mason; Niaz, 1995; Huddle and Pillay, 1996; Toth and Sebestyen, 2009. The over - dependence on the use of algorithmic strategies, without attempt at reasoning out the solution process, was evident in the problem- solving behavior of 266 high school students in a study using the think – aloud procedure while solving problem in reaction Stoichiometry (Gabel and Sherwood, 1984).

Huddle and Pillay (1996) found out that university students assumed that limiting reagent means lowest stoichiometry and some ignored the Stoichiometry of balanced equations when solving the problems. In a study conducted by BouJaude and Barakat (2000), forty grade 11 students were required to provide explanations when solving eight Stoichiometry problems. These students successfully solved traditional problems using algorithmic strategies, but lacked conceptual understanding when solving unfamiliar problems. Similar findings have been documented with introductory College Chemistry Students (Nakhleh, 1993; Niaz, 1995). Schmidt and Jigneus (2003) interviewed four students in order to obtain in depth understanding of the problem solving strategy that they used when solving four Stoichiometry problems. All

students were found to use reasoning strategies to solve easy problems. However, when solving more difficult or higher order problems most of the students resort to algorithmic strategies. One reason for the over- reliance on algorithmic procedures suggested by researchers was lack of understanding of the chemical concepts that was further supported by their inability to solve problems, different from the ones that were used during instructions (Bodner and Domin, 2000).

Drummond and Selvaratnam (2009) have reported in their study on Chemistry students' competence that many students try to solve Chemistry problems using standard procedures that they have memorized. This suggests incomplete in intellectual skills and strategies to handle chemistry problems. Therefore, Chemistry educators should develop strategies that increase competence in cognitive strategies and this can lead to more efficient learning and problem solving in particular. Jacobson and Obomanu (2011) reported on the effect of problem - solving instructional strategies on students' achievement and retention in Chemistry. In their results, they recommended that teachers should as much as possible use activity-based instruction strategies so as to improve cognitive development amongst students. Activity based instructions do not only enhance achievement but also motivate students to solve problem at hand.

A study by Ochonogor (2012) has shown that achievement in Chemistry can be enhanced if educators use problem solving approach in their tasks particularly in practical aspects. The results of Ochonogor's research study revealed a significant difference in achievement level between students taught Chemistry Practicals using problem- solving approach and those taught by conventional method. From these findings one may deduce that problem-solving approach motivates students to work harder towards a specific problem solution and educators should set up learning activities that are more problem based. POGIL activities for this current study are

more based on problem solving approach as students working in small groups are required to identify possible solutions to various presented Stoichiometry problems.

Based on evidence drown from research papers, one could really see that most of the authors have recommended active based activity, problem based approach , students interaction and verbal communication as some of the major factors that may enhance achievement in Chemistry.

2.2.5 The mole concept and interpretation of chemical formulae and equations

The mole concept is an integral part of Stoichiometry computations. However, several researchers have reported a widespread confusion over the mole among teachers and students. (Dierks, 1981; Schmidt, 1990; Stave and Lumpe, 1995; Case and Fraser, 1999; Furio, Azcona and Guisasola, 2002; Pekdag and Azizoglu, 2013). This reported confusion of the mole concept by teachers may directly impede the effectiveness of the teaching and learning process of a particular topic at classroom level. Probably is because of this confusion that many teachers and students have developed a general impression that the mole concept is a difficult topic to teach and to understand. The findings from educational research studies should be used as tools for addressing the existing teaching and learning problems at classroom level.

Dierks (1981) carried out an extensive literature review and discussed the difficulties of the introduction and the use of instruction of the mole concept. The main learning difficulties he pointed out were the abstract nature of the expression ‘amount of substance’ and the diverse meanings attributed to the word mole such as unit mass, portion of substances, and Avogadro’ s number. In a study that involved more than 600 secondary school students, Schmidt (1990) observed how students carried out Stoichiometry calculations. He noted that students equaled the

proportion of molar masses of the reacting substances to the proportion of combination of masses without considering the Stoichiometry coefficients. Stave and Lumpe, (1995) investigated the understanding of the mole concept by secondary students and their use of it in solving of problems. They verified that some identified the mole with a number of particles, while others identified it with the mass in grams. They have also pointed out that students in their study were incapable of transferring meaning between concrete level and the sub –micro level when solving problems, and had insufficient understanding of the concepts. Case and Fraser (1999) carried out a study on first year Chemical Engineering students' understanding of the mole and they reported that problems that students have are fundamental and not function of the system of units used. Furio, Azcona and Guisasola, (2002) carried out a review of the relevant bibliography on the difficulties of the mole concept. Their review about the mole concept concluded that lack of understanding of the concepts "amount of substance" and mole manifested by students is strongly connected to teachers' ideas and to the methodologies used in the teaching of Chemistry.

Confusion of the mole concept has been attributed to various pedagogical meanings given to it by educators and students. Before 1961 the term "mole" was used to refer to a quantity of something that contained units such as Avogadro s' number (Padilla and Furio-Mas 2008). Therefore, today's many students and educators still do not understand that mole is a unit for the quantity "amount of substance" and measures the number of particles of a substance (Milton and Mills 2009). Another historical perspective that led to the confusion of the mole concept is the usage of ontological meaning of mole given by Ostwald which refers to mole as mass instead of amount of substance (Padilla and Furio-Mas, 2008). This confusion is still common in various textbooks.

Pekdag and Azizoglu (2013) have analyzed semantic mistakes and didactic difficulties in teaching the concept "amount of substance". They reported that semantic mistakes in representative Chemistry textbooks stemmed from missing concepts, the usage of knowledge at incorrect level, the use of the amount of substance as equivalent to mass, molar volume or molar mass. These findings are in agreement with a study carried by Stromdahl, Tullberg and Lybeck (1994), whereby only 3 out of 28 teachers had conceptualized the amount of substance in a manner consistent with the International system of units (SI). This could be clear evidence as to why the amount of substance was deemed difficult to understand. Therefore more concrete cognitive teaching strategies such as problem based approach, and inquiry learning should be incorporated in the teaching and learning of this concept. One important conclusion drawn from a research project by Garritz and Padilla (2008) is that, in order to grasp a fairly clear comprehension of 'amount of substance', teachers and students must distinguish between this concept and the concepts of mass, volume, and number of elementary entities, as well as know the relationships between them.

2.3 Process-Oriented Guided Inquiry Learning (POGIL)

Process-Oriented Guided Inquiry Learning (POGIL) is a widely used active learning approach that was pioneered in Chemistry (Minderhout and Loertcher, 2007). POGIL involves creating an environment in which students are actively engaged in mastering a discipline and developing essential skills by working in self- managed teams on guided inquiry activities (Spencer, 1999; Hanson and Wolfskill, 2000). Currently there are published POGIL materials for General, Organic, Physical Chemistry and Biochemistry courses (Staumanis, 2004; Farrell, Moog and

Spencer, 1999). The effectiveness of POGIL in Chemistry courses have been reported by various researchers such as: (Straumanis, 2004; Minderhout and Loertscher, 2007; Lewis and Lewis, 2008; Schroder and Greenbowe, 2008; Brown, 2010).

The objectives of POGIL as outlined by Hanson (2004) are as follow:

- To develop process skills in the areas of learning, thinking and problem solving.
- To engage students to take ownership of learning.
- To increase students-students and students-instructor interactions.
- To improve attitudes towards Chemistry and Science.
- To enhance learning with Information Technology.
- To develop supporting process skills in teamwork, communication management and assessments that are essential for the work place.

2.3.1 POGIL strategy and achievement in chemistry

Process- Oriented Guided Inquiry Learning (POGIL) approach has been implemented in various Chemistry courses. Schroder and Greenbowe (2008) implemented POGIL instructions in Organic Chemistry module with the aim of addressing students' understanding of nucleophilic substitution reaction mechanisms. Their report showed an improvement in the performance of students who were taught by POGIL mode of instruction compared to Traditional Lecture classes. Minderhout and Loertscher (2007) reported that POGIL instructions were implemented at Seattle University, whereby Biochemistry students have been taught exclusively by POGIL approach without any traditional lecture component since 1997. At the end of the Biochemistry course, most students reported feeling confident in their acquired knowledge as well as

substantial gain in independence, critical thinking and respect for others. According to Spencer (1999) the effectiveness of POGIL instructions in General Chemistry does not only increase students' performances, but also decreases the number of students who withdraw from the course. The same views were also shared by Straumanis (2004).

Brown (2010) reported that, the inclusion of POGIL based learning exercises had improved grade outcomes for the students who were enrolled for Medicinal Chemistry module at East Tennessee State University. Moreover, Brown (2010) revealed that POGIL activities encouraged active engagement of students with the materials and provided immediate feedback to the instructor.

Pedretti (2010) investigated the use of inquiry-based activities and its effect on students' attitude and conceptual understanding of Stoichiometry. This study showed that students' attitudes toward mole calculations improved after using inquiry-based activities. The findings of this study further stipulate that there was not a significant difference between achievement levels of the inquiry based group and that of the lecture based group. But, this could be attributed by the fact that inquiry based activities need time to be practiced both by teachers and students.

2.3.2 Some major research findings on the effectiveness of POGIL in various Chemistry courses

The effectiveness and achievement rate of POGIL groups has been assessed at a range of institutions and for a variety of chemistry courses (Farrell, Moog and Spencer, 1999; Hanson and Wolfskill, 2000; Hinde and Kovac, 2001; Lewis and Lewis, 2005; Straumanis and Simon, 2006). Several common findings and outcomes identified in some of these studies are as follow:

- Students drop out and loss of interest in Chemistry is lower for POGIL than traditional methods.
- Students' understanding of Chemistry contents is generally sound for POGIL than traditional methods.
- Larger proportion of students' population showed greater interest in POGIL lessons over traditional methods.

An extensive study that compared the performance of General Chemistry students taught using a traditional approach and those taught using POGIL method was carried out over a period of four years 1990-1994 (n = 420) Farrell, Moog and Spencer (1999). From this study, it was found that the dropout rate decreased from 21.9% (traditional) to 9.6% (POGIL). Moreover the average percentage of students obtaining an A or B symbol increased from 52% to 64%.

POGIL approach has been reported to improve the performance of Chemistry students usually taught in large lecture groups. More often the most common mode of teaching a large class group is by recitation. However, it has been widely reported that this method does not yield meaningful understanding of scientific concepts. POGIL approach was implemented in a General Chemistry module at a large, public university in the United States of America and the outcomes of this implementation showed a notably shift of students examination results from lower scores to higher scores(Hanson and Wolfskill, 2000). Another scenario of using POGIL in teaching big class groups was reported by Lewis and Lewis (2005) whereby one of the three lecture periods of General Chemistry lessons per week was optionally replaced with POGIL

based teaching materials. The effect of this replacement reportedly produced improved average examination scores in students who attend the POGIL sessions.

Barthlow and Watson (2014) investigated the effect of POGIL teaching to reduce alternative conceptions about the nature matter held by high school learners. The two researchers compared the impact of POGIL strategy versus the conventional teacher based teaching and the results of this study revealed that learners who were taught through POGIL activities had fewer alternative conceptions about the nature of matter. Moreover, Barthlow and Watson (2014) reported that the performance in the posttest of both female and male learners in their study was equally rated. This means that POGIL as a teaching strategy does not favor gender. Stoichiometry is one of the chemistry sections in which students have been reported to have many alternative conceptions about many aspects such the mole concept, limiting reagents and meanings of subscripts in chemical formula units (Shcmidt, 1994; Huddel and Pillay, 1996). Therefore it is essential that chemistry teachers and lecturers start intensely testing the effectiveness POGIL strategy in other areas of chemistry such as Stoichiometry. The motive for carrying out this research was to a certain extent fueled up by the existing empirical studies that have reported a positive impact in the reduction of alternative conceptions in various sections of chemistry.

Degale and Boisselle, (2015) conducted a study about the effect of POGIL on the academic performance and confidence in Organic Chemistry. They reported that after POGIL instructions, students who took part in the research study showed an improvement in their academic performances. A similar study was conducted by Chase, Pakhira and Stains (2013) whereby these they explored the impact of implementing POGIL in discussion sections of General Chemistry and of Organic Chemistry. The results indicated that there was not a significant

impact on most measured attributes such as exam grade, attitudes and retention after the implementation of POGIL teaching. However, the observed trends seemed to favor POGIL strategy. The explanation given for the insignificance in the measured attributes was based on the fact that POGIL was only partly implemented in the discussion sessions whereas the rest of the teaching activities were still lecture based. The results of this previous study may serve as a proof to follow up researchers that the reported positive impact of POGIL teaching cannot simply be attained by partly implementing the POGIL strategy. This notion is well articulated in POGIL guideline document found on POGIL website.

Geiger, (2010) also implemented POGIL teaching in two allied health chemistry courses CHM 130 and CHM 131 respectively. The results indicated that students in CHM 130 did not cope at all with the POGIL teaching strategy as compared to those who were in CHM 131. The reasons given by the researcher show that most of students in CHM 131 lacked readiness to cope on their own during POGIL instructions. The findings of this study are in agreement with the notion of intrinsic motivation that students are expected to develop so that they would be able to cope with increasing demand and challenges of learning.

Finally it is worth noting that the positive impact of POGIL was not reported in the area of Chemistry alone but in other fields of sciences such as Biology and Engineering. For example, Brown, (2010) reported that 50% of the lecture classes in Introductory Anatomy and Physiology course were entirely replaced with POGIL teaching. The results of this study showed that the overall mean score of students rose from 76% to 89 % after POGIL instructions were introduced. Moreover the rate of students obtaining a D or F grade in final exam was reduced to a half. The

results of study basically ascertain the effectiveness of POGIL teaching as a general strategy, although its initial implementation was more in chemistry courses.

2.4 Summary

This chapter offered a theoretical framework of this study which is based on Constructivists' perspective and has incorporated Inquiry Learning, Dynamic skill theory and the Learning Cycle. The review of Literature included various research studies pertaining to teaching and learning of Chemistry in general and Chemical Stoichiometry in particular. Research studies on the effectiveness of POGIL approach in Chemistry were discussed and it appears that more research studies are needed in order to obtain substantial amount of empirical evidence pertaining to this pedagogical approach to teaching.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design of the study. All researches require decisions with Regard to sampling, instrumentation, data collection and the methods of data analysis (McMillan and Schumacher, 2001). In the current study the following methodological decisions are considered: research design, research sample, choice of appropriate instruments, data collection methods and analysis.

3.2 Research design

The choice of a research design depends on its fitness for the purpose and determines the methodology (Bordens and Abbot, 2005). For the purpose of this study a quasi-experimental non-randomized pre and post-tests control group was considered appropriate. In such a design, there are two intact groups, an experimental group and a control group. Both groups were pre-tested on the particular variable inherent to the study. The experimental group then received the treatment, while the control group receives no treatment. A quasi-experimental design is chosen because the main objective of the study was to determine the effect of a particular instructional strategy (POGIL) on the achievement level of students. It is worth mentioning that a randomized experimental design could be the best option for determining a more valid statistical effect of a teaching method, however for this particular study it was not possible to randomly assign students to various teaching groups. The study was conducted during the normal scheduled teaching sessions of the Science Foundation Programme, therefore randomly assigning students to teaching groups could have negatively affected the normal teaching routine of other

foundation courses. According to Lankshear and Knobel (2004), quasi experimental designs are often the only option to researchers in educational settings whereby randomization is sometimes impractical or unethical.

The study was a two-group pre and post-test comparative quasi experimental design as schematically explained below:

Experimental group	$\mathbf{O_1}$	x	$\mathbf{O_2}$
Control group	$\mathbf{O_1}$		$\mathbf{O_2}$

Where $\mathbf{O_1}$ is the pre-test for the experimental and control groups and was later administered as $\mathbf{O_2}$ **(** post-test) to both experimental and control groups respectively.

x = treatment on experimental group: Introducing Stoichiometry concepts using POGIL approach and POGIL work sheets only. POGIL approach is based mainly on stages of learning cycle of exportation, concept development and concept application. The control group was taught Stoichiometry concepts using conventional methods of instructions whereby a Lecturer presents explanations and examples to students. Students take notes, worked sample calculations, and completed assigned problems from their study guides. Students communicate verbally through answering and asking questions.

3.2.1 Design validity

According to Walliman (2001) the level of sophistication of the design and extent of control determines the internal validity of the experimental design. In this particular study the following factors were considered to be major threats to the outcomes of this study therefore control mechanisms are discussed below.

<u>Extraneous Variables in the study and Control measures</u>

- History
- Statistical Regression
- Diffusion of Treatment or Contamination

- History

History refers to any current or past event that may have a direct influence on the outcome of the current research study. In this study, this factor was controlled because all students on the Foundation Programme are from similar academic background. Students who normally get admitted are average performers, who came mostly from rural based schools in the northern regions of Namibia. Moreover, students who are registered on the programme are compulsorily taking all five subjects offered on the programme so, there were no various academic options that may favor a certain group of students. The chance for students to attend additional classes somewhere else was also minimal, because Foundation students have classes from morning to late afternoon throughout the week.

- Statistical Regression

This kind of threat to internal validity is linked to the tendency of subjects who score very low or high in a pre-test to score closer to the mean in the post-test regardless of the effect of treatment. In the current study this threat was controlled by the use an appropriate tool that can defuse the effect of intra and intergroup differences.

- Diffusion of Treatment or Contamination

This threat occurs when relevant intervention conditions have spread over to the control group probably due to interaction amongst research subjects and is a major concern in a quasi-experimental research. This was controlled by using groups from different academic years. The control was taken from foundation group of 2012 academic year, who were taught Stoichiometry concepts by Lecture Based Method only. The treatment group (POGIL) was taken from the Foundation group of 2013 academic year, who were taught Stoichiometry concepts through POGIL strategy.

3.3 Research sample

The research sample was comprised of two intact groups of registered Science Foundation students at Oshakati Campus of the University of Namibia in the academic years of 2012 and 2013 respectively. The control group which was taught stoichiometry concepts during the second semester of the 2012 academic year mainly by Lecture Based Method is comprised of 40 students. The treatment group made up of an intact group of 38 students was taught Stoichiometry concepts during the second semester of 2013 academic year mainly, by POGIL

strategy. The groups used were from different academic years, such that the risk of group contamination was minimized.

3.4 Data collection Instruments

The types of data collection instruments that were used to collect data are:

(i) Stoichiometry achievement test (used as a Pre-test and Post-test)
(ii) Group Assignments
(iii) An Evaluation survey Questionnaire

3.4.1 Stoichiometry achievement test (pre and post- test)

According to Alias (2005), an assessment test involves systematic gathering of evidences to judge students' demonstration of learning. An assessment test may focus on one or more of the learning domains such as cognitive, affective or psychomotor domain. According to various cited references in the literature section of this study, good understating of Stoichiometry requires students to be able to explain, interpret, evaluate and apply mathematical operations in chemical context. Most of the stated test items fall under the cognitive domain. In this study the researcher intended to measure the level of understanding of Stoichiometry concepts that were attained by using POGIL instructional strategy. Therefore, stoichiometry achievement tests were administered.

- Development of the Stoichiometry test

Based on the nature of this study the researcher deemed it necessary to develop specific test instruments that were quite relevant in terms of curricular content and in consonant with the level of the subjects involved in this particular study. The main themes that were covered by the pre

and post tests are Relative Masses, Formula Stoichiometry, Chemical equations Composition Stoichiometry, and Reaction Stoichiometry, Limiting and excess reagents. The Stoichiometry test was developed based on steps outlined by Treagust (1988) as follow

(a) Examining related literature – this step aims at identifying documented problem areas on Stoichiometry. Extensive literature review on the teaching and learning aspects of stoichiometry was conducted.

(b) Identifying propositional knowledge- this step aims at identifying concepts and basic propositional knowledge statements which are necessary for students to understand stoichiometry. In this study propositional statements was formulated by combining various resources such as General Chemistry text books, recommendation from related research papers, the authors own personal experience of teaching stoichiometry topic at both grade 12 and foundation level respectively. The author's own observations on comments and responses from students during lecture time.

(c) Validating the prepositional statements.

(d) Developing Stoichiometry test items: At this stage formulated prepositional knowledge were used to guide the writing of the Stoichiometry test.

(e) Pilot testing of stoichiometry test questions.

- Validity and Reliability of the Stoichiometry test

The main purpose of undertaking this task was to ensure that, statements provided are scientifically accurate body of knowledge so that students' responses could be compared with scientifically accurate views. Two lecturers from Hifikepunye Pohamba Campus with qualifications in Chemistry and Science Education and more than ten years of teaching

experiences were tasked to scrutinize the test and render second opinion. Instrument validation forms were used to complete this task (see appendix 6).

The reliability of the Stoichiometry test was assessed using the intra- scorer reliability test. The reliability of the test items was determined by carrying out a pilot study with a volunteer group of thirty Foundation students from Khomasdal Campus. The same test was administered twice (T_1, T_2) on different occasions. The reliability of the test was determined by the correlation between the scores of T_1 and T_2. A reliability coefficient of 0.72 was obtained.

3.4.2 Evaluation Survey

A questionnaire is a collection of questions which all research participants are asked to respond to (Airasian and Gay 2003). This question should be clear, concise and straight forward in simple possible language. In this study, this instrument was used to gather data on students' views regarding the use of POGIL instructional strategy in the teaching and learning of Stoichiometry concepts. A Questionnaire in the form of 4- point Likert type scale was used to collect data. Each respondent was expected to indicate the extent of his/her agreement to an item. The following perception levels were used.

Strongly agrees = 4

Agrees = 3

Disagree = 2

Strongly disagree = 1

- Development of the questionnaire

The Questionnaire was constructed by the researcher based on procedures obtained from relevant literature review. Since the questionnaire was constructed by the researcher, there was a need to validate its content. Content validating – rating form used by Li et al. (2008), was adapted to validate the questionnaire. Three selected professionals from the field of science and mathematics education were tasked to validate the questionnaire. (see appendix 8)

3.5 Data collection procedures

In this section, the actual activities pertaining to data collection were discussed and illustrated. In describing these activities, schematic diagram (figure 3.1) illustrates the main research procedure.

3.5.1 Pre-testing and post-testing for the control group

The collection of data started during the fourth week of August 2012 with pretest administered to the control group. A total of 40 students wrote the pre-test during the morning hours. The pretest was administered in order to obtain the level of Stoichiometry knowledge that students had prior to Foundation Stoichiometry. The test scripts were all collected and marked by the researcher who is a Lecturer for the module. The marked scripts were handed over to a second chemistry Lecturer for moderation and verification of the marking. The percentage raw marks were recoded using Microsoft Excel. The marked scripts were eventually put in one box and kept safe in a store room where students could not access them.

After the control group had written the pre-test, it was then introduced to Stoichiometry concepts through lecturing methods. During the lecture slots a lecturer introduced a topic of the lesson to students. Sometimes an introduction of the lesson was started with questions and students were expected to suggest their possible answers. More often only some few students were willing to give their answers, while the majority remain passive listeners. Most of the assessments work was completed on individual bases with few assignments and practicals that were done by group work. By the end of each and every lecture slots, students were given questions to practice on their own during their free time and were expected to report back to the lecturer when they experienced problems with any particular question. The teaching of Stoichiometry with control group lasted for a period of three weeks and thereafter the pretest was administered again as posttest. The test scripts were all collected and marked by the researcher who is a lecturer for the module. The marked scripts were handed over to a second Chemistry lecturer for moderation and verification of the marking procedures. The percentage raw marks were recoded using Microsoft Excel. The marked scripts were eventually put in one box and kept safe in a store room where students could not access them

3.5.2 Pre-testing of the POGIL group

The collection of data for the POGIL started during the first week of August 2013. The same pretest that was written by the control group of 2012 was administered to the POGIL group. The same pretest was administered in order to obtain the level of Stoichiometry knowledge that students had prior to Foundation Stoichiometry. The POGIL group was comprised of a total of 38 students who wrote the pre-test during the morning hours. The test scripts were all collected and marked by the researcher who is lecturer for the module. The marked scripts were handed over to the second Chemistry Lecturer for moderation and verification of the marking

procedures. The percentage raw marks were recorded using Microsoft Excels. The marked scripts were eventually put in one box and kept safe in a store room where students could not access them.

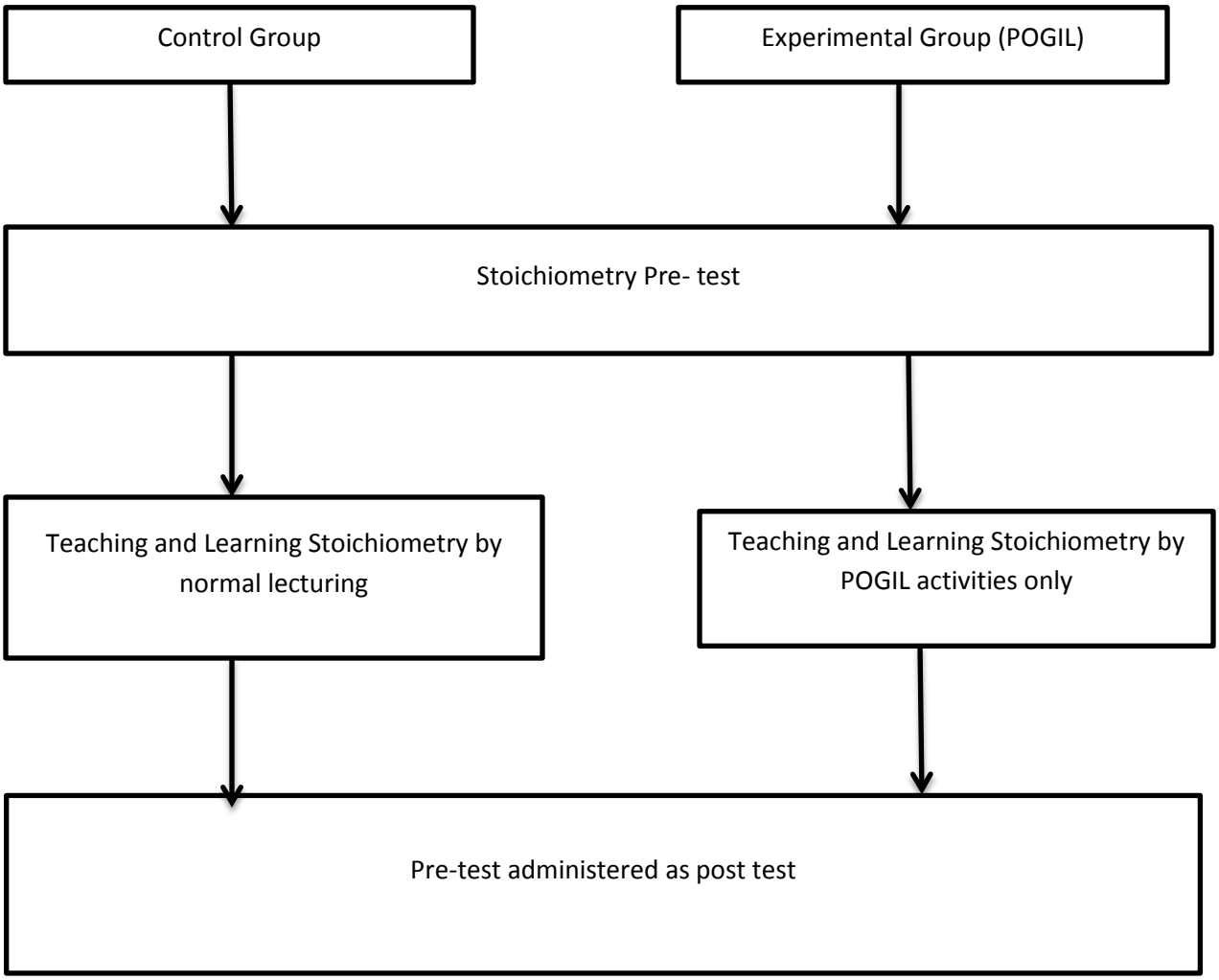
3.5.3 Treatment of the POGIL group

The teaching of Stoichiometry by POGIL group started a week later after the group had written the pre-test. The first two lessons were mainly preparatory lesson for POGIL activities. Students were allocated to specific POGIL groups of 3 to 4 students. The allocation to various groups was based on gender balance as well as differences on individual capabilities. This was done in order to attain group diversity and homogeneity amongst various groups. Each student within a group was given a role to play during a particular POGIL activity. The roles are manager, presenter, recorder and reflector. These roles were often exchanged between group members on rotational basis. During the first two lessons students were given simple Stoichiometry activities such as quizzes and puzzles. This was mainly done in order to introduce students to group activities and also to allow group members to get to know each other. Each group was given a group file whereby all the activities for the group were kept.

A typical POGIL lesson was started with an Introduction and Presentation of the POGIL teaching model by the facilitator. A sample of a POGIL teaching model was often presented in different forms such as tables, diagrams, with follow up questions (see appendix 7). After the introduction, students within their groups would start analyzing the model and work on follow up questions. During this time of the lesson called Exploratory, students are trying to comprehend the POGIL activities in the model by answering presented questions. The Exploratory phase is ended with a short presentation by a presenter from each group. The second phase of the lesson

known as concept formation, involves the construction of new ideas, terminologies by group members with help from of the facilitator. During concept formation as a facilitator you should walk around the groups and give necessary supports through explanation and probing. The last phase of the POGIL class known as concept application, involves the application, contextualization and evaluation of the learned model. This was done by answering more advanced questions presented in the model as well as those questions that are raised by various group members. Students were often given group assignments for assessment purpose. The teaching of Stoichiometry by POGIL activities lasted for a period of 5 weeks and thereafter the pre-test was administered again as post-test.

Figure 3.1: The schematic diagram of the research procedure.



3.6 Research Ethics

It is well understood by many researchers that issues pertaining to research ethics are crucial to any empirical research study. At the onset of the study, a request for research ethical clearance was sought through Unisa and subsequently an approval was granted by the Unisa Research Ethics Review Committee (appendix 1). Moreover several efforts were made such that students were not disadvantaged in any form during the period of the study. Since the study was carried out under normal teaching slots of the foundation programme, the researcher found it necessary to seek approval from the coordinator of the Science Foundation Programme. After several considerations by the Science Foundation management, an approval letter (appendix 3) to conduct the study was then granted. The researcher also made an effort to inform students at the onset of the study, that their real names will not be used or revealed in any publication or report of this study.

3.7 Data analysis

In this section, the techniques for data analysis are presented. The analysis was used to help to answer three research questions which guided this research study. The three questions are: "What is the influence of Process Oriented Guided Inquiry Learning instructions on the achievements of Science Foundation students in stoichiometry problems? Does the use of POGIL approach enhance conceptual understanding of Stoichiometry concepts in chemistry Foundation classes? Does the use of POGIL approach facilitate the learning of stoichiometry concepts in chemistry foundation classes?"

Hypothesis testing:

An analysis of Covariance (ANCOVA) was performed on the pre-test and post-test performance scores. ANCOVA statistical test was used to test the following hypothesis.

H_0: There is no statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

H_1: There is a statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

3.6.1 Data analysis strategies

Quantitative data analysis strategies were mainly used in this research study. Quantitative data analysis strategies were carried through exploratory and inferential statistical analysis techniques. Exploratory and inferential statistical analysis techniques were used to study descriptive attributes on achievement scores, perceptual trends as well as relationships on performance as pertaining to the effect of the POGIL intervention. In addition to quantitative approach, students' solutions from selected test and assignment questions from both groups were qualitatively analyzed and interpreted for conceptual understanding.

3.6.2 Exploratory data analysis strategies

Exploratory analysis was carried out on the achievement scores of both the control and POGIL groups. This data generated initial descriptive statistics on group performance in both pre- test and post- test. The descriptive statistics such as the means, standard deviation, highest and lowest scores were compared for both research groups. Furthermore an evaluation questionnaire was

administered to the POGIL group after they had completed with all POGIL lessons. The questionnaire was used to solicit students' views on the use of POGIL activities in the teaching and learning of Chemical Stoichiometry. Data from the questionnaire were also analyzed and discussed by descriptive statistics.

3.6.3 Inferential data analysis strategies

Inferential statistical analysis using a Statistical Programme for Social Sciences (SPSS) was performed on the pre-test and post-test scores of both control and POGIL groups in order to answer question one of the research study. The inferential strategies applied included:

- The Pearson correlation test was performed on the pre- test and post-test marks, in order to validate the ANCOVA assumption of linearity of relationship between the covariate (pre-test score) and the dependent variables (post-test scores).

An Analysis of Covariance (ANCOVA) was performed on the pre-test and post-test performance scores. ANCOVA statistical test was used to determine if there was a significant difference in the performance on the post-test between the control and POGIL groups with pre-test as covariate. Associated with the ANCOVA is the assumption of homogeneity of the regression slopes. The assumption of equal regression slopes was then confirmed by a between subject test.

3.7 Summary

In Chapter 3, the description of the research design and methods of data collection were discussed. It also outlined the development of data collection instruments and their validity and reliability. The Chapter is concluded with the discussion of major data analysis that was used to interpret the collected data for this research study.

CHEAPTER 4

PRESENTATION OF RESEARCH RESULTS

This chapter presents the results of the statistical analysis that was carried out in this study. The results include the descriptive statistics and ANCOVA test. Associated with analysis of covariance results are ANCOVA data compliance assumptions that ensure reliable analyses of the results.

4.1 Descriptive statistics of the pretest and post test scores

A total of 78 students completed this study, 40 students in the control group and 38 students in the POGIL group. The gender representation was 45 females (58 %) and 33 males (42%). Descriptive statistics for the pre-test and post-test scores are listed in Table 4.1. The statistics in the table were generated from test achievement scores of the Stoichiometry test which was written as pre-test and post-test by both teaching groups. The control group had a mean pre-test score of 28.0 (*SD*= 5.5) and posttest mean of 54.4 (*SD*= 9.2) which is an increase of about 26 %.

The POGIL group had a mean pre-test score of 28.1 (*SD*= 5.3) and a posttest mean of 60.6 (*SD*= 8.2), which represents an increase of about 33%. From these statistics, it appears that the performance of both groups in the pre-test were comparable, although the pre-test mean for the POGIL group was slightly greater than that of the control group by 0.1 %. The post-test means for both groups all show an increase from their respective pretest means but the posttest mean for the POGIL group is greater than that of control group by 6.2 %. At this stage one may probably conclude that the POGIL teaching method seems to be more effective than the traditional teaching method, but this conclusion could be considered as a statistically biased conclusion. The main point is that the groups' performance was slightly not equally matched on their pre-test

scores. These results are not surprising because the study used intact class groups therefore group performances could not be equally matched due to the lack of random selection of subjects. However, this particular weakness was to a certain degree controlled by using ANCOVA test. ANCOVA test to a certain extent controls preexisting differences between the control and experimental groups (Dimitrov and Rumrill, 2003). The ANCOVA results are presented under section 4.2.3.

Table 4.1: Teaching groups' descriptive statistics: Pre-test and Post-test

Index	**Statistics in pre-test**		**Statistics in post-test**	
	Control group	**Experimental group**	**Control group**	**Experimental group**
Mean %	28.0	28.1	54.4	60.6
S.D.	5.5	5.3	9.2	8.2
Highest score	40	39	70	75
Least score	18	20	38	44
Number of students *N*	40	38	40	38

4. 2 Analysis of Covariance (ANCOVA), to answer the research question one

An ANCOVA test was used to determine whether the post-test results for the control and POGIL groups were different after the pre-test scores were considered as covariate. Associated with analysis of covariance results are ANCOVA data compliance assumptions that ensure reliable analyses of results. These assumptions are test of linear relationship between the covariate and

dependent variables and the homogeneity test of regression slopes. ANCOVA test was carried with a significance level of 0.05.

4.2.1 Test of linear relationship between the covariate and dependent variables

H_0 There is no a significant linear relationship between the covariate (pre-test scores) and dependent variables (post-test scores).

H_1 There is a significant linear relationship between the covariate (pre-test scores) and the dependent variables (post-test scores).

Pearson correlation was used to establish the correlation between the covariate (pre-test scores) and the dependent variable (post-test scores). The results are given in the Table 4.2 below.

Table 4.2**:** Correlations between the covariate (pre-test scores) and dependent variables (post-test scores).

		pretest score %	posttests scores %
Pre-test score %	Pearson Correlation	1	.661**
	Sig. (2-tailed)		.000
	N	78	78
Post-test scores %	Pearson Correlation	.661**	1
	Sig. (2-tailed)	.000	
	N	78	78

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.2 shows the observed correlation coefficient, r between the covariate and the dependent variable to be 0.661. This represents a moderate positive correlation between the covariate and dependent variable. The p value is less than 0.05, ($p < 0.05$), hence the null hypothesis is

rejected. This implies that there is a significant linear relationship between the covariate (pretest scores) and the dependent variables (posttest scores).

4.2.2 Test of homogeneity of the regression slopes

H_0 The relationship between the covariate (pre-test scores) and dependent variable (post-test scores) does not differ significantly across the groups.

H_1 The relationship between the covariate (pre-test scores) and dependent variable (post-test scores) differs significantly across the groups.

Table 4.3 The Homogeneity test of the regression slopes

Dependent Variable: post -test score %

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Group * pretest	71.048	1	71.048	1.822	0.181

Table 4.3 gives a p- value of 0.181 for the interaction of the groups and the covariate. The null hypothesis is retained since p> 0.05. Therefore, the relationship between the covariate (pre-test scores) and dependent variable (post-test scores) did not differ significantly across the groups.

4.2.3 ANCOVA results

Research Question 1: *What is the influence of Process Oriented Guided Inquiry Learning instructions on achievements of Science Foundation students in Stoichiometry problems?*

H_0: There is no statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

H_1: There is a statistical significant difference in the Stoichiometry post-test mean scores of learners exposed to POGIL and those in the control group.

Table 4.4: Summary of ANCOVA on the effect of the use of POGIL approach on the post-test achievements score.

Tests of Between-Subjects Effects

Dependent Variable: post-test scores %

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	3548.349[a]	2	1774.174	45.002	.000	.545	90.004	1.000
Intercept	1889.778	1	1889.778	47.934	.000	.390	47.934	1.000
Pre-test	2804.023	1	2804.023	71.124	.000	.487	71.124	1.000
Groups	709.261	1	709.261	17.990	.000	.193	17.990	.987
Error	2956.831	75	39.424					
Total	263818.0	78						
Corrected Total	6505.179	77						

b. Computed using alpha = .05

Table 4.4 shows that the group as the main effect, is significant on the study participants' achievement in Stoichiometry F (1,75)= 17.990 , $p < 0.05$ (see Table 4.4). The *partial Eta*

squared of 0.193 indicates that about 19.3 % of student gains were related to the teaching method used. Hence, the null hypothesis is rejected.

Table 4.5 and Figure 4.1 show respectively that the experimental (POGIL) group's estimate marginal mean 60.5 % was greater on the post-test than that of the control group 54.5 %. This analysis shows that POGIL approach enhances the students' achievement in learning Stoichiometry while controlling for the effect of pre-testing. Based on the results of the ANCOVA reported here, the null hypothesis which stated that there is no statistical significant difference in science foundation students' posttest mean achievement score in Stoichiometry after following POGIL approach in the learning of Stoichiometry as compared to the mean score of the control group was rejected.

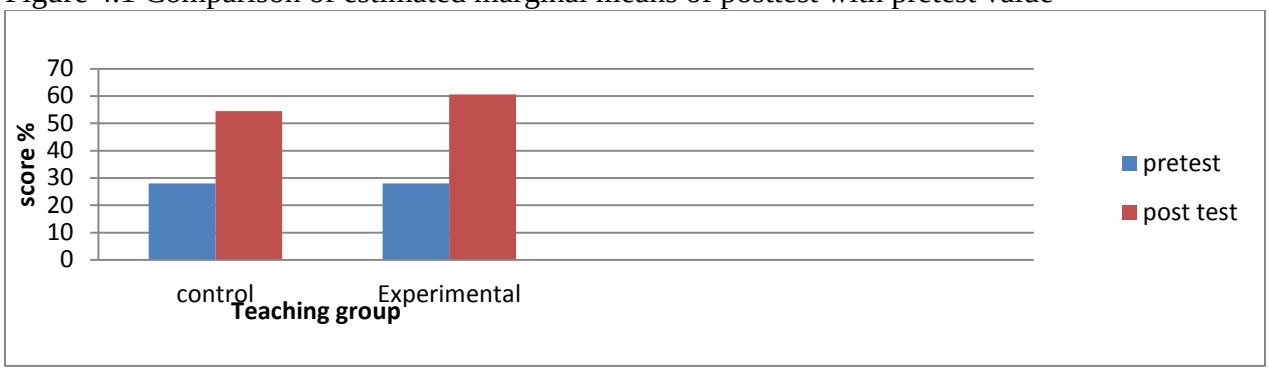
Table 4. 5 Estimated posttest s' marginal for both groups

Dependent Variable: posttest scores %

class group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
control group	54.497[a]	.993	52.519	56.474
POGIL group	60.530[a]	1.019	58.501	62.559

a= Covariates appearing in the model are evaluated at the following values: pretest score % = 28.06.

Figure 4.1 Comparison of estimated marginal means of posttest with pretest value



4.3 Analysis of improvements on specific test items

As the ANCOVA results shows statistical significance in the performance between the post-test marginal means of the POGIL group and the control group, the following analysis in Table 4.6 was done to determine the conceptual improvement on specific Stoichiometry sections that were covered in this research study. Data in table 4.6 show that the POGIL group showed greater improvements in most of the test items. The POGIL group showed the highest improvements (65%) in questions on reaction Stoichiometry and limiting reagents. In comparison the control group recorded improvements of 49% and 53% in the section reaction Stoichiometry and limiting-excess reagents respectively. These differences could be attributed to the fact that this sections of the test required students to relate the given quantities to the relative reaction ratios of the reaction. Students in the POGIL group were given group activities with a model on relative ratios, whereby they had to discuss the application of these ratios on a given scenario. Students in the control were often given individual handouts to practice on how to manipulate molar rations in calculations and most of the lessons were conducted through whiteboard explanations and demonstrations.

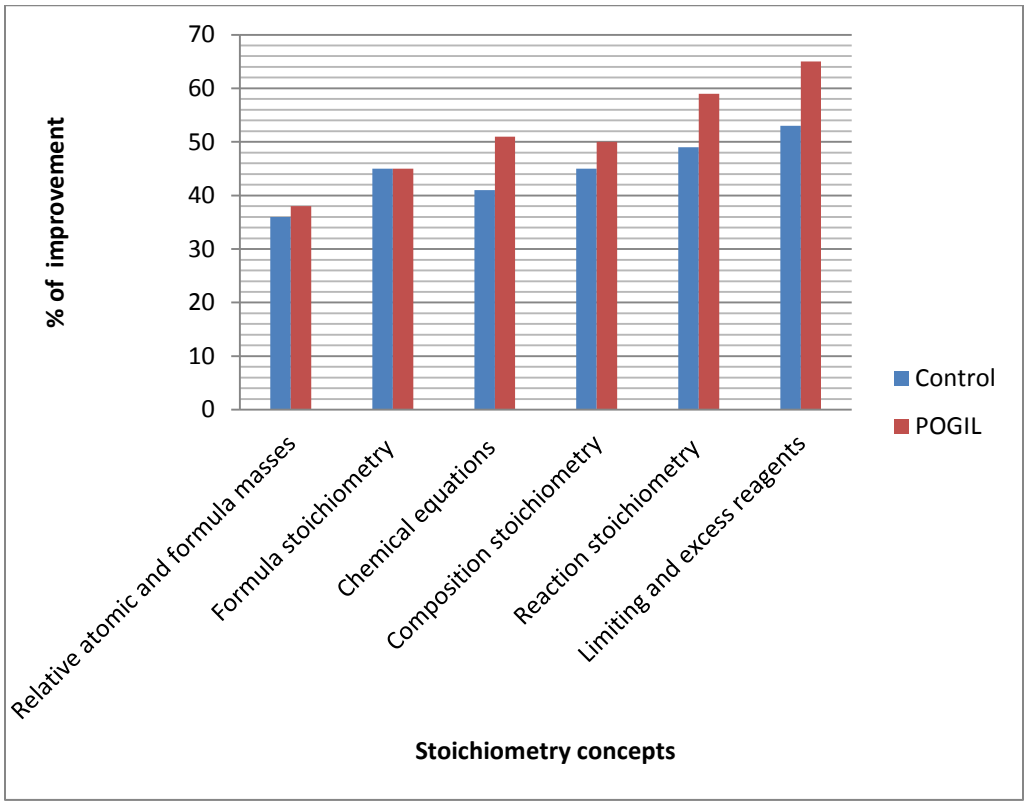
Table 4.6: Analysis of average improvements of students on specific test items

Sub topic of the test	**Question number**	**Control group performance %**			**POGIL group performance %**		
		Pre test	**Post test**	**Improvement**	**Pre test**	**Post test**	**Improvement**
Relative atomic and formula masses	**1, 2, 3, 4, 5**	21	57	36	20	58	38
Formula stoichiometry	**6,7 8, 9**	18	63	45	20	65	45

Chemical equations	**10 and 11**	15	56	41	14	65	51
Composition stoichiometry	**12**	10	55	45	9	59	50
Reaction stoichiometry	**13**	5	53	49	6	65	59
Limiting and excess reagents	**14**	3	56	53	3	68	65

From the graph in Figure 4.2, it appears that the control group had performed almost equally as the POGIL group in the sections of atomic masses and formula Stoichiometry. This could be explained by many computational calculations that were included in these particular sections of the test. The control group was given lots of activities to practice and it appears that it had prepared them equally as their counterparts. Although the improvements in these sections (Atomic Masses and Formula Stoichiometry) were comparable for both teaching groups, the POGIL had a slight upper hand due to the fact that many students in the control group could not answer Question 8. Question 8 required students to apply an understanding of fixed mass promotions of individual elements in compounds. Most students in the Control group performed unnecessary calculations while their counterparts in the POGIL group managed to figure out the correct answer without calculations. This could probably be attributed to POGIL class activities that enabled students to have a thorough discussion before embarking on calculations.

Figure 4.2: Comparative % of students' improvement on specific test items



4.4 Presentation of results from selected students' solutions, to answer the research question 2.

Does the use of POGIL group enhance conceptual understanding of Stoichiometry concepts in Chemistry Foundation classes?

Four questions were selected for detailed analysis of students' solutions. The four questions were selected because the scores of the two groups differed substantially. The analysis of students' solutions was conducted by the researcher and another Chemistry lecturer. Selected solutions were analyzed in terms of complete ideas, strategy and conceptual understanding.

Question 7 and 8 from the Stoichiometry test

Q7 The simplest mass ratio of hydrogen: oxygen in 18.00 g of water (H_2O) is (1: 8). Determine the simplest mass ratio of hydrogen: oxygen in 36.00g. (Give a reason or show how you got your answer)

This question was equally answered by both control and POGIL group respectively. However, there was a notable difference in the approach used by the two groups. More than 50% of the Control group used several steps of calculations to answer this question, whereas the POGIL group based their answers on the law of constant composition hence the given mass ratio is the same whether you have 18 g or 36 g of water. The approach used by the POGIL group represents meaningful conceptual understanding of composition of chemical compounds.

Q8 The mass percentage composition of Hydrogen element in 18 g of water (H_2O) is about 11.1 %. Determine the mass percentage composition of Hydrogen in 36. g of water (Give a reason or show how you got your answer).

This question was similar to question 7, because it is also based on chemical composition. The approaches used by both groups were similar to those used in Q7. Most students from the control group tried to answer this question by carrying unnecessary steps of calculations with some calculations leading them to correct answer but some did not yield the desired solutions. The POGIL group members used the idea of constant mass percentage composition of elements in compounds without necessary carrying out calculations. The approach used by the POGIL group represents meaningful conceptual understanding of composition of chemical compounds.

Question 11 from the Stoichiometry test

11 *In a certain experiment the total mass of reactants (Mg and O_2) that has been reacted completely in closed vessel is 138.29 g. Suggest whether the total mass of the products will be:*

A more than 138.29 g

B less than 138.29 g

C equals to 138.29 g

Reason……

This question was an attempt to test students' understanding of conservation of mass/ matters during chemical reactions. This question was poorly answered by the control group, with the majority of students opting for destructor B as the correct answer. The reasons given were based on the idea that some of the products or reactants will be lost during chemical reaction. This is an indication that although most of the students in the control group were able to correctly balance chemical equations, it seems they did not understand as to why chemical equations have to be balanced. More than 50% of POGIL students opted for correct answer C and their reasons ware correctly based on conservation matter during chemical reactions. The differences between the two groups could be linked to the difference in teaching methods used. The POGIL group used POGIL materials with critical questions and probably this has prompted them to discuss reasons with regards to balancing chemical equations.

Question 14 (a) from the Stoichiometry test

Limestone ($CaCO_3$) reacts with dilute hydrochloric acid as follow. Use this equation to answer the following question.

$$CaCO_{3\,(s)} + 2HCl_{\,(aq)} \rightarrow CO_{2\,(g)} + CaCl_2\,(aq) + H_2O\,(l) \text{ at STP}$$

(a) 1mol of $CaCO_3$ is added to 2 mol of HCl. What will be the limiting reagent? Explain.[2]

This question was selected because it was poorly completed by the control group. The average performance of students from the POGIL group was twice larger than the Control group. Most students from the control groups have opted for $CaCO_3$ as a limiting reagent and reasons given are based on the argument that one mole will get finished up first than two moles. These students did not grasp the idea of comparing the exact molar ratio from the balanced equation and the given number of moles. Some students have answered it correctly by carrying out calculations through factor label or ratio method but this was not necessary if students had properly understood the linkage between the given number of moles of reactants and the molar ratio from the balanced equation. The POGIL group did better than the control because one of the POGIL teaching models used during group discussion was based on determining the limiting reagent from several given reactant proportions. Students were actively manipulating the molar ratios and at the same time reasoning on how molar ratios determine the limiting reagent.

Question 5 from the Assignment

The average Relative atomic mass of Calcium has a numerical value 40.08 and its Molar mass also has the same numerical value 40.08. Does it mean that these two numbers represent the same amount of Calcium? Explain your reasoning with appropriate examples.

This question aimed at testing whether students had understood concrete meanings of related Stoichiometry quantities such as atomic mass and molar mass. The performance of both groups in this question was almost similar. Despite this observed similarity, the POGIL group was slightly better with their reasoning than the control group. Most of the solutions from the control group were correct as they managed to figure out that the two quantities do not represent the

same amount. However, their mental reasoning lacked concrete understanding of concepts. More than 65 % of the control group gave reasons that are mainly based on the difference in the units used. For example, most students' reasoning was "atomic masses are measured in (amu) and molar mass in (gram)". About 58% of POGIL group managed to give concrete reasoning which was based on the idea that atomic mass is the average mass of a single atom whereas the molar mass is the mass of about 6.022 x 10^{23} atoms. Again this may represent a certain degree of conceptual upstanding that students from the POGIL group had probably gained from group discussions about relative atomic mass and molar masses. The researcher discovered that most students from both groups were very good at using these two quantities in numerical problems but they lacked concrete meanings of these two quantities.

4.5 Presentation of results from the Evaluation survey, to answer the research question three

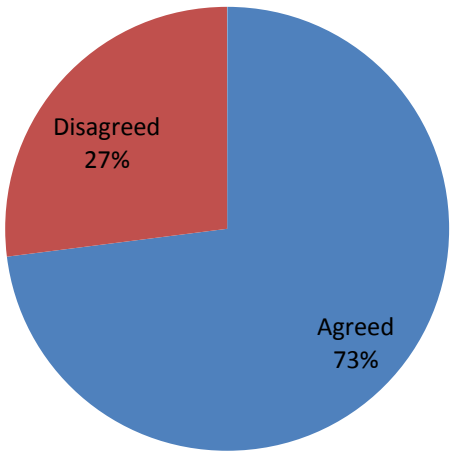
Does the use of POGIL group facilitate the learning of Stoichiometry concepts in Chemistry Foundation classes?

Data from Table 4.7 show the total response frequency given by students in each of the rating category. The frequencies and percentages for each questionnaire item were also calculated and are represented by the two numerical values in the table cells. The last two columns of Table 4.7 show students' response frequencies grouped into two categories of "Disagreed" and "Agree" respectively. Overall the results from table 4.7 show that the majority of the students agreed to all six questionnaire. This is confirmed clearly by the difference in the percentage frequencies for the overall disagreed (27%) and agreed (73%) respectively.

Table 4.7: Results of students' perception rating on the impact of POGIL groups on the learning of stoichiometry concepts

Composite one –way frequency table : POGIL group and the learning of stoichiometry						Frequencies per total Agreed and Disagreed categories	
Questionnaire item	**Frequencies per rating category**						
	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**	**Total**	**Disagreed**	**Agreed**
1. I find it easy to express my thoughts, when I work in POGIL group	3 8 %	7 18%	21 55 %	7 18%	38	10 26%	28 74%
2. Working with POGIL group, members helped me improve on how I solve concepts	2 5%	11 32 %	22 58%	3 5 %	38	13 34%	2 66 %
3. I think that I will learn more about stoichiometry when working in POGIL group than would if I worked by myself	3 8%	7 18%	20 52 %	8 21%	38	10 26%	28 74%
4. I enjoyed taking part in POGIL group work.	2 5%	5 13%	21 55%	10 26.%	38	7 18%	31 81%
5. I understand stoichiometry concepts in POGIL groups better than reading from textbook or lecture notes	3 8%	6 16%	23 61%	6 16 %	38	9 24%	29 76%
6. I think POGIL activities should be used in teaching all chemistry topics	5 5.3%	6 16%	17 45%	10 26%	38	11 29%	27 71%
Total	18 8%	42 18 %	124 54%	44 19%	228	61 27 %	167 73%

Figure 4.3: Percentage Response frequency to the overall Agreed and Disagreed categories



Analyzing the frequency responses per questionnaire item, a notable variation across individual categories was noted. The major trend shows that most of the students responses fall under the "Agree" category rating whereas the "Strongly disagree and strongly agreed categories scored the least number of response rates. One of the survey statement that displayed a much greater variation in students' responses is statement 3 *"I think that I will learn more about stoichiometry when working in POGIL group than would if I worked by myself"*. 74 % of the students have agreed to this statement as compared 26 % who disagreed. Some of the reasons given by students who agreed with statement 3, 4 and 5 are represented in scanned Evidence 1 shown.

Strongly agree = 1	Agree= 2	Disagree=3	Strongly disagree =4

Evidence 1

3. I think that I will learn more about stoichiometry when working in POGIL than would if I worked by myself. [2]
Reason: I can easily get feedback from my group members

3. I think that I will learn more about stoichiometry when working in POGIL than would if I worked by myself. [2]
Reason: you can compare your answer to those of your members

3. I think that I will learn more about stoichiometry when working in POGIL than would if I worked by myself. [2]
Reason: It is easy to get help from others when you get stack.

3. I think that I will learn more about stoichiometry when working in POGIL than would if I worked by myself. [2]
Reason: No need to study for test because you learn already in the group work.

4. I enjoyed taking part in POGIL group work. [2]
Reason: Because you gain more understanding than in lecture classes.

4. I enjoyed taking part in POGIL group work. [1]
Reason: You learn to think and debate with others.

5. I understand stoichiometry concepts in POGIL groups better than reading from textbook or lecture notes [2]
Reason: POGIL classes are more enjoyable than lecture classes.

5. I understand stoichiometry concepts in POGIL groups better than reading from textbook or lecture notes [1]
Reason: Lecture classes are sometimes boring

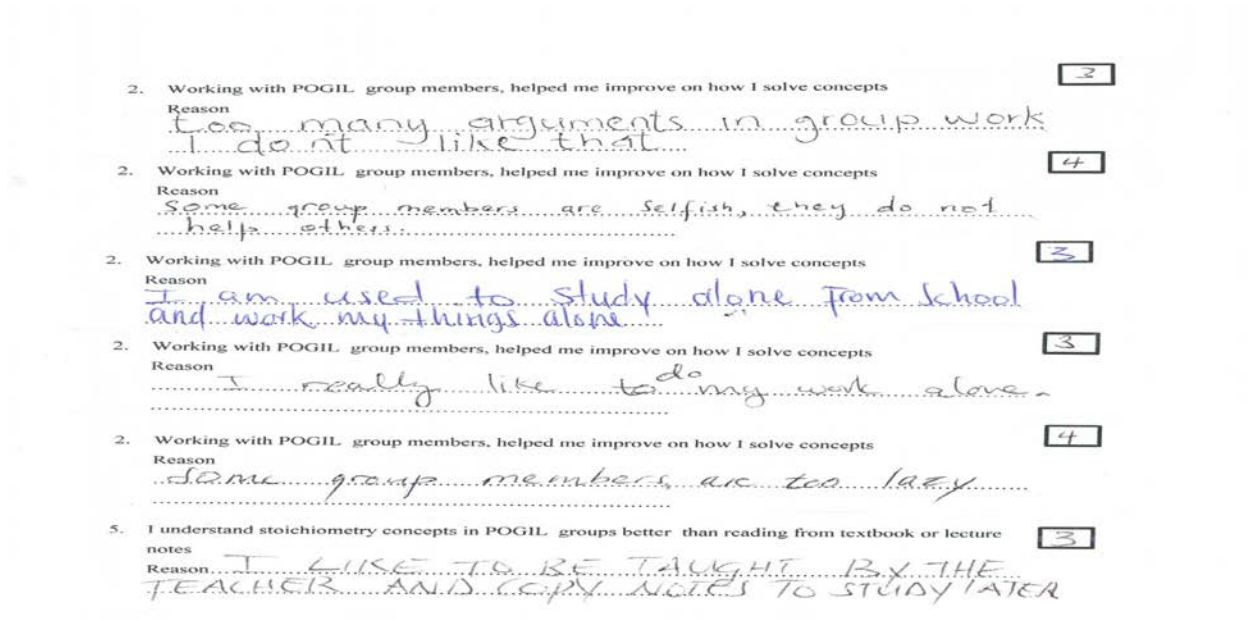
The reasons given by students who agreed with statement 3, 4 and 5 clearly demonstrate a change in mindset towards learning by these students. These students seemed to have gained a certain degree of confidence in POGIL learning over lecture classes to which probably they have been exposed for most part of their schooling. Teaching and Learning Strategies such as POGIL

have been reported to have a positive impact both in academic performance and attitudes towards learning. The results of this study are in agreement with the latest related studies (Villagonzalo 2014; Sedumedi 2014; Degale and Boisselle, 2015). The results from these researchers have proven that inquiry instructions have a positive impact on student achievement. However, some researchers such as Chase, Pakhira and Stains (2013) reported that the implementation of POGIL during class discussion section of a General Chemistry course had limited to no impact on students' grades and attitude toward Chemistry. These researchers however asserted that POGIL did not negatively affect students' learning but instead it has the potential to enhance it. In this particular study more than 50% of the total students who responded to the evaluation survey have expressed full confidence with POGIL activities. It was however noted that a few students in each of the category rating scale of the evaluation survey, favoured direct instructions from the lecturer, as they have expressed it through their supporting reasons to the specific survey statements.

The highest disagreed responses (34 %) were recorded under statement two of the questionnaire. Statement two states that "*Working with POGIL group, members helped me improve on how I solve concepts*". Most of the reasons given by the students who disagreed with statement two were related to the lack of collaboration between group members as well as individual preference to study alone. Some of the reasons given by students are shown in the scanned evidence 2 shown.

Strongly agree = 1	Agree= 2	Disagree=3	Strongly disagree =4

Evidence 2



2. Working with POGIL group members, helped me improve on how I solve concepts [2]
Reason
too many arguments in group work I do nt like that

2. Working with POGIL group members, helped me improve on how I solve concepts [4]
Reason
Some group members are selfish, they do not help others.

2. Working with POGIL group members, helped me improve on how I solve concepts [3]
Reason
I am used to study alone from school and work my things alone

2. Working with POGIL group members, helped me improve on how I solve concepts [3]
Reason
I really like to do my work alone.

2. Working with POGIL group members, helped me improve on how I solve concepts [4]
Reason
Some group members are too lazy

5. I understand stoichiometry concepts in POGIL groups better than reading from textbook or lecture notes [3]
Reason I LIKE TO BE TAUGHT BY THE TEACHER AND COPY NOTES TO STUDY LATER

The responses from the scanned exhibits clearly show that some of the students felt that the learning supports from POGIL group were not so effective due to poor collaboration among some group members. These responses are however not surprising, as they are part of the technical challenges associated with cooperative learning groups (Wilhelm, 2007). According to Wilhelm (2007), inquiry as a component of cooperative learning requires maximum discipline of group remembers as well as proper direction from the facilitator. To achieve good results from a cooperative learning group such as POGIL group, students must develop trust for one another

and solve conflict amicably (Johnson and Johnson, 2009). Most of the students who took part in this particular study were however were not used to studying in groups. Although the researcher made an attempt to allocate students to specific groups before the commencement of the study, it seems the duration for that was too short.

From this analysis one may conclude that POGIL activities had to a certain extent facilitated the learning of stoichiometry in this particular study, despite the fact that a few number of students' perception rates were in disagreements with the use POGIL groups in learning Stoichiometry. This could be attributed to the fact that POGIL strategies were implemented for the first time to this particular research group of students and therefore it may require more time and training such that all students get used to this learning approach.

4.6 Summary

This chapter presented and discussed the results of statistical analysis of data obtained from Stoichiometry tests in order to measure the impact of POGIL lessons on the performance of students in Stoichiometry. A detailed analysis of selected students' solutions was carried out, in order to determine the influence of POGIL activities on students' conceptual understanding of Stoichiometry concepts. Furthermore, an analysis of students' responses to some of survey items was done in order to obtain the overall views of students towards the use of POGIL activities.

CHAPTER 5

SUMMARY, IMPLICATIONS, LIMITATIONS AND CONCLUSION

This chapter gives a brief overview of the main findings of the study, implications, limitation as well as recommendations for the future. The summary of the findings are discussed in light of the research questions and hypothesis.

5.1 Summary of the main findings

The purpose of this study was to investigate the influence of POGIL on students' performance in Stoichiometry related concepts.

The design of the study was a quasi- experimental pre-posttest. The pre-test was used to determine the level of Stoichiometry knowledge that students have before being introduced to two different teaching models which were the Traditional Lecture based instructions and the POGIL strategies respectively. Moreover, detailed analysis of selected students' solutions was carried out in order to determine the gain in conceptual understanding.

The first research question which guided this research study was "*What is the influence of Process Oriented Guided Inquiry Learning instructions on achievements of Science Foundation students in Stoichiometry problems?"* In answering this research question the descriptive statistics of the pre-test and post-test were calculated and thereafter analysis of covariance was performed. ANCOVA results showed that there was a significant statistical difference in

achievement when comparing the adjusted mean scored by the control group and the adjusted mean score obtained by the students in the POGIL group. The results produced a p- value less than 0.05 levels. This analysis showed that POGIL approach may have enhanced the students' achievement in learning Stoichiometry while controlling for the effects of pre-testing. This conformed to the findings of Minner, Levy and Century (2010), which claimed that students showed greater science achievement when involved in Guided Inquiry Lessons than when involved in Traditional Lectures. Furthermore, Marais and Combrinck, (2009), reported that the use of structured work sheets and concrete models made a noticeable impact with the problems first year students experienced in stoichiometry.

Moreover, quantitative analysis (Table 4.6) on specific Stoichiometry topics that were covered in the test showed that the POGIL group recorded a considerable improvement in the post-test results compared to the control group. The improvements were more noticeable in test items that covered reaction Stoichiometry and determination of limiting and excess reagents (Figure 4.2). Several research studies have reported difficulties with the teaching and learning of reaction Stoichiometry involving limiting and excess reagents (Drummond and Selvaratnam (2008); Selvaratnam, Mavuso (2010); Selvaratnam (2011). Recommendations made by some of these researchers included the use of concrete submicron diagrams and models that provide clearer pictures of chemical reactions. POGIL activities used in the current study had incorporated several models such as diagrams and graphical representations and this probably could be linked to a greater improvement in the post-test marks of the POGIL group.

The second research question asked: *"Does the use of POGIL group enhance conceptual understanding of stoichiometry concepts in Chemistry Foundation classes?"* In answering this question, detailed analysis of selected students' responses was carried out. These responses were selected on the ground that they were common and also displayed a significant difference between the two groups. The analysis of student s' solutions provided evidence of enhanced conceptual understanding amongst the POGIL group in various ways as outlined below:

- More of the POGIL group students were able to give concrete reasons for their answers that they had obtained through numerical calculations or multiple choice.
- The POGIL group demonstrated enhanced understanding of linking various Stoichiometry concepts.
- There was a greater tendency amongst the control group to perform calculations although the given problem required simple reasoning, an indication of a lack of conceptual understanding.

The third research question which guided this study was*:* *"Does the use of POGIL group facilitate the learning of stoichiometry concepts in Chemistry Foundation classes?"*

To ascertain the impact of POGIL strategy on students' attitudes towards learning Stoichiometry, an evaluation survey was administered to the experimental group students after they had covered Stoichiometry. The data from the survey indicate that 73% of the responses were recorded under the "agreed" category, which favours the learning of Stoichiometry through POGIL groups. In comparison, 27 % of the survey responses indicated the preference of Lecture based lessons. The results from this survey are not surprising, particularly that it was the first time that these students were completely taught Stoichiometry by Inquiry learning approach. Other related

studies (Villagonzalo, 2014; Sedumedi, 2014; Degale and Boisselle, 2015), have reported similar results whereby the majority students expressed confidence with the POGIL group work. Most related studies that have reported positive gain in students' attitudes were however conducted over a longer period of time such as a semester or full academic year. In the current study, the teaching lasted for about 5 weeks and probably some of the students were still in the process to getting adjusted to this new learning approach. It is clear that one size does not fit all but based on these results, the researcher has gained confidence in POGIL groups and probably if students are continuously being exposed to POGIL strategies, the percentage of those who disagreed are likely to decrease.

5.2 Research Implications

Many educators acknowledge that it is not possible to transmit knowledge intact from the head of the instructor to the head of the student. Also much research exists to documents that real understanding and learning require restructuring on the part of the learner. The results of this research study may contribute to the teaching and learning of Stoichiometry in various ways such as at classroom level, instructional design and research based teaching. The teaching and learning implications that have culminated from this study are discussed in following sub-sections.

5.2.1 Research implications pertaining to the teaching and learning of Stoichiometry

During the period of the 20th century, many researches in chemistry education were more focused on identifying students' problems in learning chemistry such as students' alternative conceptions, problem solving strategies as well conditional factors that directly have an impact

on learning (Niaz and Robinson, 1992; Nakhleh, 1993; Shcmidt, 1994; Huddel and Pillay, 1996). During the current century (21th), some of these long identified problems may still persist in our educational systems. New ideas of doing things are at the fore front of today s' living hoods, therefore current teaching practices should respond to this call. This particular research study has highlighted the importance of student centered learning approach of Stoichiometry as opposed to teacher centered learning. Stoichiometry is regarded as a fundamental topic in General Chemistry course and therefore well-grounded understanding of Stoichiometry serves as the prerequisite to other sections of chemistry. Studies have indicated that the teaching of Stoichiometry has been predominately characterized by procedural and algorithmic teaching methods (Okanlawon, 2010; Bartholaw and Watson, 2014). Although these methods may promote the manipulation of variables through certain techniques, they however do not enhance conceptual understanding of underlying concepts. A student may master very well the procedures used to calculate the number of moles of a substance from a given mass but he/she may not have a clear understanding with regard to the meaning and magnitude of this quantity in real life situation. In this particular study students were introduced to Stoichiometry concepts through POGIL activities. During POGIL activities students have to think and discuss first in detail the underlying concepts, before solving numerical problems. POGIL activities were designed in such a way that, the learning process follows a conventional learning cycle. Students were actively involved in deriving major conclusions instead of them being provided with conclusion or certain formulae. This strategy is well in line with some of fundamental theories of learning such as that of Piaget and Vygotsky respectively. Vygotsky s' social constructivist theory supported the use of language in learning and emphasized that students must interact socially during the learning process (Powel and Kalina, 2009). Furthermore, Vygotsky

formulated the concept of Zone of Proximal Development (ZPD), which identified the potential of an individual when provided with assistance from a knowledgeable adult or more advanced peer (Artherton, 2013).

Statistical analysis of the pre and post tests scores indicates a significant difference in achievement between the control and experimental group. The POGIL group performed better during in the post-test as compared to the Lecture based group. The findings of this study are in agreement with those of previous studies such as (Villagonzalo, 2014; Sedumedi, 2014; Degale and Boisselle, 2015). The control group also improved, which indicates that lecture based teaching was not completely inferior, however it can be probably used to complement the POGIL method or the two methods should be used on alternating basis.

The major difference that the researcher has identified between the two groups is that the POGIL group performed better especially on problems that required conceptual understanding such as those of conservation of matter and limiting reagents. A study by Tigere, (2014) revealed that grade 12 learners demonstrated low level of both algorithm and conceptual problem solving proficiency in Stoichiometry concepts. The recommendations from this study emphasized that both algorithm and conceptual skills are essential in solving stoichiometry problems therefore, teachers should employ teaching methods that foster deep understanding such as problem based, project based and inquiry based teaching. POGIL strategies used in this study are in line with the recommendations suggested by Tigere, (2014), and the results of this study confirm that students who were taught Stoichiometry concepts by POGIL strategies were indeed successful in conceptual problems such as limiting reagent problems. The focus of this study was mainly on the impact of POGIL on students' achievement and their demonstrated conceptual understanding, but other researchers such as Nworgu and Otum (2013), have reported in their

findings that Guided Inquiry with analogy has also enhanced the acquisition of science process skills.

Another advantage of POGIL strategy that was noted in this particular study is that, students in POGIL groups were able to recognize existing gaps in their knowledge such as alternative conceptions, invalid scientific principles and outdated scientific principles. For example, it was discovered in one of the POGIL lessons that the majority of students believed that relative atomic and molecular masses were equivalent to the corresponding molar masses. However, after the POGIL group was introduced to these concepts through separate POGIL work sheets, students started to notice a clear distinction between the two concepts. A clear distinction could only be drawn through POGIL work sheets, whereby each theme was introduced separately in a systemic manner that eventually led students to discover that atomic mass is a microscopic property whereas molar mass is macroscopic. The Lecture based group was introduced to the same concepts through general classroom discussion as well as diagrammatic illustration on a whiteboard but their answers in the post-test has proven that these two concepts were not clearly well understood by the majority of this group of students. The results are in line with the fundamental theories of learning such as Piaget s' constructivism theory. Piaget s' constructivism theory suggests that cooperative learning groups promote understating of scientific concepts through cognitive conflict and disequilibrium that eventually lead students to restructure existing ideas (Woolfork 2010). Barthlow and Watson, (2014) have also supported the importance POGIL strategy by stating that it provides students with opportunities that enable them to carry out in-depth exploration of complex topics.

The finding of this research study had also compared the achievement level of the POGIL to that of the Lecture based group under various sub-sections of stoichiometry. The overall average

performance indicates that the POGIL group had performed equally or better than the Control group in most sub-sections of Stoichiometry. An in-depth analysis of individual test items revealed that in some test items, the performances of the two groups were almost comparable. This could be attributed to the fact that POGIL activities appeared to be more effective if the concepts to be learned are more involved and require critical analysis and comparison. Some of the stoichiometry concepts such as balancing equations and calculation of formula masses are more of algorithmic oriented, therefore students from both groups who had well grasped the computational techniques managed to score good marks from these problems. However, it is worth stating that the ability to compute algorithmic problems does not necessary mean that students have understood principles that often govern these computational techniques. For example the researcher has discovered that the majority of students from the Lecture based group were successful at balancing chemical equations but they could not give the fundamental reasons for balancing chemical equations. These are some of the aspects that should be considered when preparing POGIL worksheets. If the content of the POGIL worksheet does not focus on fundamental principles that students may need to understand, then the ultimate objectives of POGIL lessons may not be achieved.

The results of this particular study might be relevant at classroom level, as it demonstrate the application of a remedial teaching approach through active research work. The researcher could not however cite out any published relevant research papers that have looked at the teaching of Stoichiometry or Chemistry in general within the context of Namibian education. However an unpublished research paper by Kaundjua (2010) revealed that there are persisting mixed feelings from both teachers and learners with regard to the teaching and learning of stoichiometry at secondary education level. According to Kaundjua (2010), Physical science teachers from the

Northern Central regions of Namibia reported that Stoichiometry is one of the hardest topics to teach at secondary school level. The topic is perceived to be so difficult to such extent that some teachers may even go for an option of not teaching it at all. If this is really the case then, it implies that learners graduating from some of these secondary schools may have an incomplete knowledge of Chemistry and this consequently may constitute a huge obstacle during the course of their academic journey. Evidence of incomplete conceptual knowledge of Stoichiometry has surfaced during POGIL classes of this study. The researcher has observed during group discussions that some students had different conceptions with regard to the meaning of the mole concept. Some students thought a mole is a chemical substance that occur naturally just like elements and compounds. Through general discussions with students, it came out that some students considered Stoichiometry as a complex section of mathematical chemistry that just involves the calculation of moles, atoms and molecules without any motive to understand the underlying concepts. As it is reported in previous research papers, the level of understanding that students may attain at classroom level is heavily influenced and shaped by the teaching and learning strategies occurring during lessons (Barthlow and Watson, 2014). Therefore these research findings should be put into practice at various levels of formal education such as primary, secondary and tertiary level.

5.2.2 Research implication pertaining to the use POGIL Strategy to teach Stoichiometry and contribution to knowledge

POGIL as an educational philosophy and a teaching strategy was to a certain extent successfully implemented in this particular research study. Literature review about the use POGIL and other related Inquiry Learning methods indicates that the strategy has been implemented in different settings, and the results conform to that of the current study (Lewis and Lewis, 2005; Brown, 2010; Barthlow, 2011; Sedumedi, 2014; Villagonzalo, 2014; Degale and Boiselle, 2015). All of the studies reported positive gain in achievement which is attributed to the use of inquiry learning to teach several chemistry topics.

In this particular study the use of POGIL group proved to be better than the Lecture based method, in various aspects such as achievement, conceptual understanding and attitude towards learning Chemistry. Students in POGIL groups were exposed to a self- directed learning approach that helped them to discover new ideas about stoichiometry and also make use of their own understandings to construct and formulate scientific principles with regard to Chemical Stoichiometry. POGIL activities were not only beneficial to the students but the facilitator has also gained substantial knowledge about the level of stoichiometry conceptions that students have demonstrated during group discussions. During POGIL group discussions, the facilitator had an opportunity to uncover general ideas and scientific principles that students demonstrated during POGIL discussions. These ideas were openly discussed and correction was made when it was necessary. This open discussion about the learned concepts is often not applicable in Lecture based classes because of the dominant nature of transferring of instructions from the Lecturer to the students.

Despite the positive gain reported from this study, it should be however stressed that POGIL strategy is a systematic approach which its ultimate goals could only be attained if it was correctly implemented. The researcher identified some of the challenges that seemed to have a significant influence on the implementation and outcomes of the POGIL strategy. Some of the identified factors are: students' prior knowledge of stoichiometry, students' perception about group work, students' proficiency in the language of learning instruction and time management from both students and the facilitator.

Students' prior knowledge seems to have a significant impact on the coverage of POGIL worksheets. It was noted in this study that, in some POGIL lessons students had demonstrated low level of prior- knowledge with regard to the content covered in the work sheets. This had resulted in group members experiencing difficulties in articulating the underlying concepts. Moreover students with limited prior knowledge often take up much time of the lesson to comprehend the content of the work sheet and consequently slow down the pace of teaching. The impact of limited prior-knowledge had initially affected the progress of the group discussions in this study to such extend that the facilitator sometimes had to initiate the discussion by giving a brief introduction and reformulate the content of the learning model. Some of the lessons had to be repeated because students could not easily conceptualize the underlying principles in a single lesson. However, the pace and the quality of group discussions gradually improved as students were often given pre-reading assignments on the topic to be covered during the POGIL lesson. Based on these findings with regard to prior knowledge, the researcher recommends that students with low level of pre-knowledge should be given prior reading activities about the POGIL topic to be covered during the lesson. This may reduce the time that students may take to uncover and understand the content of the worksheet. The notion of pre-knowledge with regard to its use in

inquiry learning was noted in other related research studies such as that of Bledsoe (2012). Bledsoe commented that lack of relevant prior-knowledge can disadvantage inquiry learning, because it may limit the level at which students engage in inquiry activities.

The effect of language was also considered as an obvious obstacle in the progress of POGIL group discussions. The medium of instructions used in most Namibian schools is English, however most people often communicate to each other in local languages that are predominately understood by the majority of the people in a particular region. Therefore, it appears that some of the students in POGIL groups of this study were not freely open to express themselves during discussions, as they were not really used to communicating in English language. POGIL strategy is based on the use of social interaction among students through verbal communication of the learned concepts. If the implementation of POGIL strategy is to be deemed successful and progressive the then students should have to attain a certain level of communication proficiency in the language instructions. One of the reported benefits of POGIL strategy is that it can enhance students' communication skills through students' interactions within their POGIL groups. The current study is well in agreement with the reported benefits but it seems that those benefits are only to be realized if several conditional factors that may have a negative impact are considered prior to the implementation of POGIL strategy.

5.3 Recommendations

Changes in society, technology and world economy are occurring at increasing faster rates. It is essential that educators at all levels of education provide students with opportunities, to acquire the knowledge and skills that they will need to survive and be successful in this increasing dynamic environment. Against this background the recommendation related to classroom practice arising from this study are summarized below:

- The teaching and learning of Stoichiometry should motivate students to formulate their own ideas as provided for in POGIL approach. This will give students an opportunity to construct their own knowledge and at the same time communicate effectively.
- Many educators believe that cooperative learning is one of the most effective strategies in improving students' achievements than traditional pedagogy. POGIL approach used in this study is an effective vehicle for creating cooperative learning environment. Therefore, it should be incorporated in teaching perceived difficult topics such as Stoichiometry.
- One of the main goals of pre-university preparatory programmes such as the Science Foundation group used in this study is to help students develop positive attitudes towards learning, which will help them to succeed in tertiary studies. In light of this research study, instructors for such programmes should adopt instructional strategies such as POGIL which provide a vehicle for the development of scientific skills, communication as well as peer learning.
- POGIL teaching is a strategy on its own, with its specific philosophical foundations and objective, therefore educators in the field should not misinterpret its meaning with other ordinal class group work. For example students may be seated in groups while working

on given task, but if that particular task is not formulated in such a way that it follows a learning cycle and probably does not fully elicit students to engage their mental capabilities then the ultimate objectives of POGIL will never be attained.

- The implementation of POGIL teaching should be considered as a gradual process rather than one shot event. Therefore the desired learning outcomes may only become a reality over an extended period of teaching activities.
- The use of POGIL in this particular study has proven that POGIL teaching requires a combined effort of the facilitator and students. Therefore there is a need for more research work on the impact of conducting an intensive training of facilitators and students before implementing POGIL strategy.
- POGIL strategy has been widely reported that it has a positive impact on achievement and attitudes of students towards chemistry (Hein 2012). This particular study is also in agreement with those reported results in previous studies but in addition to that, the current study has also identified certain conditional factors that seem to have an impact on the implementation process of POGIL strategy. These identified conditional factors are pre-knowledge level of students, students' proficiency in the language of instruction and the context of POGIL learning models/ sheets.

5.4 Limitations of the study

- The outcomes of this study should be interpreted and may be applied to other settings with appropriate cautions, as it was undertaken with a case study group of students with similar academic backgrounds.
- The Chemistry content used was entirely limited to those stipulated in the curriculum outline of the Science Foundation Programme at the University of Namibia.

5.5 Conclusion

The purpose of this study was to investigate the influence of POGIL on students' performance in Stoichiometry related concepts. The findings showed that POGIL approach may have enhanced the students' achievement in learning Stoichiometry while controlling for the effects of pretesting. Furthermore, qualitative analysis on specific Stoichiometry topics that were covered in the test showed that the POGIL group recorded a considerable improvement in the posttest results compared to the control group. The researcher therefore suggests that POGIL approach be used in the teaching and learning of Foundation Chemistry at the University of Namibia as well as at other similar programmes.

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APPENDIX 1: ETHICAL CLEARANCE

UNISA university of south africa

13 February, 2013

Mr. Abed Osmund Kaundjwa
(41604288)
Namibia

Dear Mr. Kaundjwa,

REQUEST FOR ETICAL CLEARANCE: Influence of Process Oriented Guided Inquiry Learning (POGIL) on Science Foundation Students` Achievements in Stoichiometry Problems at the University of Namibia

Your application for ethical clearance of the above study was received and considered by the ISTE sub-committee in the College of Graduate Studies on behalf of the Unisa Research Ethics Review Committee on 12 February, 2013.

The Committee is pleased to inform you that ethical clearance has been granted for this as set out in your application.

Congratulations on this interesting and relevant study. We would like to wish you well in this research undertaking.

Kind regards.

C. E. OCHONOGOR, *Ph.D; FCAI*
CHAIR: ISTE SUB-COMMITTEE

CC. PROF L. LABUSHAGNE
EXECUTIVE DIRECTOR: RESEARCH

PROF M N SLABBERT
CHAIR- URERC

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
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Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Appendix 2: Letter to the coordinator (Science foundation programme)

14 May 2013

Dear Ms Nghipandulwa,

I am Abed Osmund Kaundjwa, a final year Master's student at UNISA (St Nu: 41604288). As a requirement for the award of a Master of Science degree in Chemistry Education, I am investigating the impact of Process oriented guided inquiry learning (POGIL) on the teaching and learning of chemical stoichiometry in Foundation chemistry. I would like you to grant me the opportunity to conduct this research study with the science Foundation students at the University Namibia at Oshakati campus.

The study will follow the normal programme timetable hence there would be no interruption of the normal time schedule. The learners would also benefit from the method of instruction as it is hoped that this would enhance their understanding of the concepts.

Please do not hesitate to contact me if you have any further queries or clarifications. My contact details are as follows:

Email: aokaundjwa@unam.na Cell nu: 0812718746

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

Abed Osmund Kaundjwa

APPENDIX 3: APROVAL FROM THE COORDINATOER (SCEIENCE FOUNDATION)

18 May 2013

Re: Permission to conduct research with the Science Foundation Programme students.

I hereby grand you permission to conduct research with the Science Foundation Programme students on the topic: **Investigating the impact of process oriented guided learning (POGIL) on the teaching and learning of chemical stoichiometry in the Foundation chemistry**. We would like to learn from your findings, so a copy of the report will be highly appreciated. May I also hope that your research activities will not interrupt the normal University program.

Thank you and good luck with your research.

Yours truly

.....

Lahja Tileni Nghipandulwa
Coordinator:Foundation Program
Oshakati Campus
University of Namibia
Tel: +264 (0) 65 2232287 - Fax: - E-mail: lnghipandulwa@unam.na - Web: http://www.unam.na

Private Bag 13301, 340 Mandume Ndemufayo Ave, Pionierspark, Windhoek, NAMIBIA

APPENDIX 4: STOICHIOMETRY TEST

Student Name…….

Duration: 2hrs

Total marks: 80

Instructions

Answer all questions on the spaces provided underneath each question.
Show clearly your calculations and explanations.

1. A relative atomic mass of an atom is obtained by comparing the actual mass of the atom to……. [1]

2. Chemists often use relative atomic masses in their calculations instead of actual masses of atoms. Give an explanation for this. [2]

……

……

3. How many atomic mass units were assigned to a carbon-12 isotope? [1]

……

4. Relative atomic masses for most elements on the periodic table are referred to as <u>average</u> atomic masses. Give an explanation for this. [2]

……

……

5. Which one is heavier 100molecules of water or 100mol of water? Give an explanation for your choice. ? [2]

……

……

……

6. Use a copy of the periodic table to answer the following questions about ammonium sulfate (Diazanium sulfate) $(NH_4)_2SO_4$

a. How many elements made up this chemical compound? [2]

……

b. How many atoms make up the formula unit of this compound? [2]

…….

c. Calculate the relative formula mass of this compound. [2]

……..

d. Calculate the molar mass of this compound. [2]

…….

e. Calculate the mass of <u>two formula units</u> of these compounds. [2]

…….

f. Calculate the <u>mass of two moles</u> of this compound. [2]

…….

g. Write the symbolic formula that represents two moles of ammonium sulphate (Diazanium sulfate). [1]

……

7. The <u>simplest mass ratio</u> of hydrogen: oxygen in 18.00 g of water (H_2O) is (1: 8). Determine the <u>simplest mass ratio</u> of hydrogen: oxygen in 36.00g. (Give a reason or show how you got your answer) [2

……

……

8. The mass percentage composition of hydrogen element in 18 g of water (H_2O) is about 11.1 %. Determine the mass percentage composition of hydrogen 36. g of water (Give a reason or show how you got your answer) [2]

……

……

9. Consider a nuclear notation of an unknown atom given below

$$({}^{40}X_{20})^{2+}$$

(a) Which number is used to identify the element? Give a reason. [2]

……

……

(b) How many electrons are in this atom? Show how you got the answer? [2]

……

(c) This atom belongs to which element? [1]

……

10. Consider a reaction equation below:

$$2NO_{(g)} + O_{2\ (g)} \leftrightarrow 2\,NO_{2\,(g)}$$

(a)Write down the molar ratio of all reactants and products in the given reaction equation.[1]

……

(b)Explain the significance (importance) of molar ratios in any given reaction equation.

[2]

……..

(c) By referring to 2 NO_2 in the above equation. What does the numerical value 2 placed?

(i) Before the formula represents in this chemical representation? [1]

……

(ii) After the formula represent in this chemical representation? [1]

……

12 In a certain experiment the total mass of reactants (Mg and O_2) that has been reacted completely in closed vessel is 138.29 g. suggest whether the total mass of the products will be

A more than 138.29 g

B less than 138.29 g

C equals to 138.29 g

Reason……[2]

12 (a) A 500g of magnesium ribbon were placed into a Beaker.

(i) Write down the <u>conversion fraction</u> ratio that relate mass of magnesium to the number of moles of magnesium [1]

……

(ii) Calculate the number of moles in 500 g of magnesium ribbon. [2]

……

(iii) Calculate the number of magnesium atoms in 500g of magnesium ribbon [2]

……[2]

(iv) Calculate the mass of 8.55×10^9 magnesium atoms. [2]

……

(b) The SI unit mole was originally defined based exactly on which physical quantity? [2]

……

(c) You are given two samples of copper metal. Sample 1 is labeled 100 g Cu atoms and Sample 2 is labeled 9.48×10^{23} Cu atoms. Which sample (if any) contains many copper atoms? Show your calculation or reasoning. [2]

……

(d) Consider the following numerical quantities of element magnesium: 24.31 amu of Mg and 24.31 g/mol of Mg. Are these two quantities practically equal or not? Give an explanation for your choice. …… [2]

Explanation……

……

(e) You are provided with two samples, 5 moles of Aluminium and 5 moles of Iron. Which of the statements listed below is correct about the two samples? [2]

A. 5 mole of Fe contains more particles.

B. 5mol of Al contains more particles.

C. The two samples have equal number of atoms and equal masses

D. The two samples have equal number of particles and different masses

E. The two samples have equal masses but different number of particles

Reason……

13 Carbon monoxide gas can be oxidized to carbon dioxide through the following chemical reaction. Use this chemical equation to answer the following questions.

$2CO_{(g)} + O_{2\ (g)} \rightarrow 2CO_{2\ (g)}$ at STP 1 mol of a gas occupies 22.41 L

(a) What does the abbreviation STP stand for? [1]

……

(b) State the application of STP conditions when dealing with gas stoichiometry problems. [2]

……

……

(c) Find the volume in liter of carbon dioxide that will be produced from a complete reaction of 44.8 L of oxygen at STP. [2]

……

……

(d) Find the mass of carbon dioxide produced from a complete reaction of 44.8 L of oxygen gas.[3]

……

……

(e) Find the total mass of reactants used to produce the mass of carbon dioxide in (d). [3]

……

……

(f) If 2 L of carbon monoxide reacts completely, can we say 2 L of carbon dioxide will be produced? Is this a correct statement? [2]

Explanation……

……

(g) If 2 g of carbon monoxide reacts completely, then 2g of carbon dioxide is produced. Is this a correct statement? Explain. [2]

Explanation.....

14 Limestone ($CaCO_3$) reacts with dilute hydrochloric acid as follow. Use this equation to answer the following questions.

$$CaCO_{3\,(s)} + 2HCl_{\,(aq)} \rightarrow CO_{2\,(g)} + CaCl_{2\,(aq)} + H_2O_{\,(l)} \text{ at STP}$$

(a) 1mol of $CaCO_3$ is added to 2 mol of HCl. What will be the limiting reagent? Explain. [2]

……

……

(b) If 14 g of calcium carbonate is added to 0.2 mol of hydrochloric acid, which reactant do you use in calculations to find the mass of calcium chloride produced? Show your work and Explain. [4]

Explanation……

……

……

(c) If 8.2 g calcium carbonate were added to 100 mL of hydrochloric acid solution whose' molarity is 2 mol/L . Write down all the steps (no calculations required) that you would follow in order to find the volume of carbon dioxide produced. [4]

Steps:

……

(d) Use your steps in (C) to calculate the volume of carbon dioxide in (b). [4]

……

……

APPENDIX: 5 Chemical Stoichiometry: Assignment

Answer all questions

1. Consider the chemical formula, CO_2. Use your understanding of chemical formulas to state what the subscripts 2 represents in

(a) One molecule of CO_2 [1]

(b) One mole of CO_2 [1]

2. (a) state clearly what Avogadro's number 6.022×10^{23} represents in chemistry [1]

(b) Which one is heavier 100molecules of water or 100mol of water? Give an explanation for your choice. [2]

3. The average relative atomic mass of Mg atom is about 24.31 amu and the average actual mass Magnesium atom is 4.04×10^{-23} g .Is there a difference in terms of magnitude (size) between the two given masses? Explain clearly your answer [2]

4. Consider a chemical reaction equation below;

$2NO_{(g)} + O_{2\,(g)} \rightarrow 2\,NO_{2\,(g)}$

(a)State what the numbers placed before each chemical formula represent in a given chemical equation? [1]

(b) By referring to NO_2 explain whether the number 2 which is placed before and after the formula does represent the same thing ? [2]

(c) If 2 mol of NO was added to 1mol of O_2 in a closed flask.

(i) How many moles of NO_2 are produced? Show your work/ give reason. [2]

(ii) Do you expect any excess reactants to remain after the reaction? If there is, state which one and if no excess reagent then give a reason for that. [2]

(iii) The initial total mass of the reactants was found to be 64.01g. Would you expect this mass to increase, decrease or stays the same after the reaction. Give a reason for your choice. [2]

5. The average Relative atomic mass of Calcium has a numerical 40.08 and its Molar mass also has a numerical value 40.08. Does it mean this two numbers represent the same amount of Calcium? Explain your reasoning with appropriate examples. [2]

Appendix: 6 Stoichiometry test – validation form

My research study seeks to investigate the influence of POGIL materials in the teaching and learning of chemical stoichiometry. As part of the validation procedures, you are selected as one of the judges to rate the test instrument. After you have gone through the test please judge based on the following rating scale.

A. Content coverage

1= not well covered; 2= somewhat covered 3 = very well covered

Rating …….

Comment……

B Relevance of each question item to science foundation students

1= not relevant; 2= somewhat relevant 3 = highly relevant

Question number	Rating	Comment
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Appendix: 7 Evaluation Survey for the POGIL group

Students' views about the use POGIL activities in learning Chemical Stoichiometry concepts

Thank you for taking time to answer these questions. This questionnaire is part of a study about the impact of the use POGIL activities in the teaching and learning Chemical Stoichiometry. The responses are treated as confidential and would only be used for research purposes.

For each question use the given number codes below to select the scale that corresponds to your response.

Strongly agree = 1	**Agree= 2**	**Disagree=3**	**Strongly disagree =4**

1. I find it easy to express my thoughts, when I work in POGIL group ☐
   Reason
   ……
   ……. ☐
2. Working with POGIL group members, helped me improve on how I solve concepts
   Reason
   ……
   ……..
3. I think that I will learn more about stoichiometry when working in POGIL than would if I worked by myself. ☐
   Reason……
   ……..
4. I enjoyed taking part in POGIL group work. ☐
   Reason……
   ……..
5. I understand stoichiometry concepts in POGIL groups better than reading from textbook or lecture notes ☐
   Reason……
   ……..
6. I think POGIL activities should be used in teaching all chemistry topics ☐

   Reason ……
   ……

Appendix: 8 Evaluation survey – validation form

Dear Sir / Madam

My research study seeks to investigate the influence of POGIL materials in the teaching and learning of chemical stoichiometry.

This questionnaire is meant to measure students' perception on POGIL strategy and its impact on learning in chemistry classes.

As part of the validation procedures, you are selected as one of the judges to rate test instrument.

After you have gone through the questionnaire please judge based on the following rating scale.

1= not relevant; 2= somewhat relevant 3 = highly relevant

Question number	Rating	comment
1		
2		
3		
4		
5		
6		

Appendix: 9 A sample of POGIL work sheet

POGIL: Work sheet #1 (adapted, from http:// www.pogil.org

What does chemical stoichiometry involve?

Why? Measurements of quantities make up part of daily activities. Although very often we do not take our measurements seriously / accurately. Scientists and chemists in particular do take measurements of quantities more accurately because it helps them in preparing the desired products in the right amounts without necessary wasting the starting raw materials/ chemical reagents. The branch of chemistry that deals quantitative relationships of chemical substances is known as stoichiometry.

Model I Stoichiometry quantities and Conversion factors

Name of quantities	Common units of measurements	Definition of the quantity
1. Mass	**Grams (g)**	**Amount of matter in an objet**
2.		
3.		
4.		
5.		
6.		

1. Which one of the quantities above is used to count particles of substance?

2. Which one of the quantities above is a property of a solution?

3. Can you convert from one stoichiometry quantity to another? If yes how do you do it?

4. What is a conversion ratio?
5. Give several examples of conversion ratios that you have used before.
   (a)

   (b)

   (c)

   (d)
6. Can you express conversion factors as fractions? If yes express your conversion factors in (Q3 d) as fraction

Model 2 Practice with conversion ratios. Complete this table below

Conversion ratios	Convesion ratio as fraction	Inverse of the coversion fraction
1kg : 1000g	1kg/1000g	1000g/1kg
1mol C :12.01g		
1mol : 6.022 x 10^{23} particles		
1mol N_2 : 24 L at STP		
1L petrol : $ 11.00		
1dm^3 : 1000 mL		
1mol O_2 : 2molH_2		
1 dozen of eggs : 12eggs		

Use the table above to answer the following questions(use the factor label method and the show cancelletion of units

1. How many moles of carbon atoms are in 100g of carbon?
2. How many atoms of Mg are in 10 mol Mg
3. How may Liters of petrol would obtain by paying $500.00
4. How many eggs are are in 200 dozens
5. How many Liters of argon gas are in 10 mol of argon
6. How many of moles O_2 are needed to react with 7 mol H_2

Did you realize that for any form of conversion by factor label method the genaral formul is

Answer = ~~known quantity~~ x unknown quantity/~~known quantity~~

Always identify the known quantity and unknown quantities in the given problem qustion.

APENDIX: 10 PERCENTAGE RAW MARKS (PRE AND POST TESTS)

Group	Pretest score %	Post test score %
1	20	48
1	31	55
1	28	52
1	21	42
1	35	66
1	29	38
1	28	45
1	18	48
1	28	46
1	19	38
1	25	51
1	29	60
1	23	50
1	26	55
1	36	69
1	31	68
1	33	60
1	33	65
1	24	50
1	21	48
1	28	52
1	25	51
1	28	45
1	35	60
1	25	45
1	28	53
1	18	40
1	35	68
1	27	58
1	40	66
1	34	60
1	31	69
1	36	70
1	38	68
1	25	55
1	26	54
1	29	50
1	26	46

1	24	55
1	24	58
2	30	66
2	27	70
2	20	56
2	26	58
2	28	60
2	20	50
2	38	75
2	25	44
2	28	55
2	25	53
2	33	66
2	32	60
2	35	75
2	31	69
2	28	63
2	29	64
2	21	55
2	31	51
2	33	66
2	29	56
2	34	64
2	24	48
2	20	58
2	31	60
2	33	75
2	36	58
2	20	56
2	24	45
2	36	74
2	25	58
2	21	63
2	39	60
2	28	65
2	28	68
2	28	66
2	21	50
2	23	55
2	29	68