

**GRADE 12 LEARNERS' MISCONCEPTIONS ASSOCIATED WITH THE RATE OF
CHEMICAL REACTION: A CASE STUDY OF CAPRICORN SOUTH DISTRICT IN
THE LIMPOPO PROVINCE.**

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DECLARATION WITH REGARD TO INDEPENDENT WORK

I, **MATSEBA MAROME BESTER** identity number _____ and student number _____, do hereby declare that this research project submitted to the Central University of Technology, Free State for the Master of Education (Post Graduate Studies), is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment of the requirements for the attainment of any qualification.

18/01/2023

SIGNATURE OF STUDENT

DATE

DEDICATION

This dissertation is declared to my Mom Rebecca Rampati Matseba, and my wife Mokgadi Johananna Matseba, who strived under all circumstances to make me the person I am today. I will forever cherish their support, love, and encouragement in believing in me such that I pursue my studies.

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ABSTRACT

This study examined Grade 12 learners' misconceptions associated with the rate of chemical reaction at schools located in Capricorn South District in the Limpopo Province. Learner performance in Physical Sciences remains a critical area of concern for various key stakeholders with vested interest in education within the broader South African context. There is a critical need to develop meaningful conceptual understanding of Physical Sciences topics in particular to ensure sustainable development of scientific literacy and coherent inculcation of requisite scientific skills.

Reaction rate is a fundamental chemistry part which forms a basis for comprehension of subsequent chemistry areas. A Reaction Rate Concept Test was developed in the form of a questionnaire and administered to a group of physical sciences learners, to collect data and statistically analyzed. This study was based on conceptual change approach as the strategy which will be used in the teaching and learning contexts to minimize or eliminate misconceptions (alternative conceptions) held by most learners at high school level. The results showed that only few (about 34%) of the learners mastered certain concepts while the majority (about 66%) of the learners struggled to deal with the same concepts. This means that most learners do not understand the effect of factors affecting the reaction rate. There were serious misconceptions from the learners that have a significant impact on their academic performance. These misconceptions shown to have a high resistance to change, and the teachers should always guard against and be vigilant enough to deal with them as soon as they emerge.

KEYWORDS: Reaction Rate Concept Test, conceptual change approach, alternative conceptions, Limpopo Province

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ACRONYMS

ACT	Alternative Conception Test
CA	Curriculum Advisor
CKCP	Chemical Kinetics Calculation Problem
DH	Departmental Head
HOD	Head of Department
LCP	Le Chatelier's Principle
NSC	National Senior Certificate
RRAT	Reaction Rate Achievement Test
RRCT	Reaction Rate Concept Test
SATL	Systematic Approach to Teaching and Learning

CHAPTER 1

INTRODUCTION AND ORIENTATION OF THE STUDY

1.1 INTRODUCTION

In the meeting held on 22 January 2020 by physical sciences teachers and Curriculum Advisors (CA), the chief examiner's comments in the diagnostic report for Grade 12 end of year examinations in 2019 were discussed and it was found that some learners' responses shown some misconceptions in reaction rate and subsequent topics. It was indicated that learners seem to have misconceptions rooted from their everyday experiences and interaction with their outside world, because most of their answers to the questions represented the alternative concepts. In that meeting, the teachers were warned to avoid giving examples from learners' everyday situations and encouraged to always use correct scientific concepts in their respective teaching and learning environments. Lamichhane, Reck and Maltese (2018:1) defined misconceptions as the "the old, the bad, and the ugly" prior knowledge, ideas, or conceptions that the learners have that hinder their further learning in science.

In that meeting, most teachers revealed a few misconceptions prevailing in their learners:

- That some learners defined reaction rate as the speed at which reactants convert to products;
- The rate of the forward reaction increases with time from the mixing of the reactants;
- When a system is at equilibrium and a change is made in the conditions, the rate of the favoured reaction increases, but the rate of the other reaction decreases;
- Many learners cannot differentiate clearly between the characteristics of completion reaction and reversible reaction, because their prior knowledge of reactions that proceed to completion seems to have influenced their conception of the equilibrium reactions. The definition of reaction rate is still a challenge to many learners. The key

words in the definition such as “per unit time” and “change” were often omitted (DBE diagnostic report, 2018:168).

The most common definitions observed were:

- The rate at which reactants are changed into products (not mentioning of the amount, volume, mass and concentration made), and
- The speed at which reactants convert to products.

From the misconceptions mentioned by the teachers regarding their learners, it is apparent that the teaching and learning of chemistry at high school level is more difficult and cumbersome to most of the learners. Chemistry is the science of matter involving all the changes it undergoes. Chemistry education at high school level covers all the fundamental concepts that learners should understand and the chemical processes that lie beyond everyday phenomena. It is imperative that more comprehensive studies are needed in chemistry education to look for ways to make it easier for learners to grasp chemical concepts. Teachers play a major role in how learners understand and learn the chemistry concepts as taught in their respective classes. However, some of these misconceptions might be emanating from teachers as they reflect their already existing conceptual constructions, problem-solving skills, or processes onto the learners. This becomes true in most cases when abstract concepts are being taught, because teachers are sometimes confused by what is happening.

Some of the teachers have highlighted the fact that learners are holding misconceptions regarding effects of changing concentration and volume on overall equilibrium and K_c in a system at equilibrium. Abstract concepts are usually difficult for learners to understand, and it is necessary to be aware of them at an early stage and develop proper teaching strategies to eliminate them as they are persistent to formal teaching. Learners have great difficulty in understanding reaction rate, especially when solving numerical equilibrium problems. The majority of the learners could not comprehend that reaction rate and reaction yield are two different concepts and are not directly related to each other.

1.2 BACKGROUND OF THE STUDY

Seçken and Seyhan (2014:348) conducted an analysis of high school students' academic achievement and anxiety over graphical chemistry problems about the rate of reaction among the Eleven Graders in Turkey. They used the Reaction Rate Achievement Test (RRAT) and the Anxiety Scale on the Use of Graphs to examine the students' understanding of chemical kinetics. They found that many students' responses were inconsistent with the scientific perspective. The results showed that the learners did not frequently use “particulate” and “mathematical” modeling as required by the curriculum. In order to evaluate the success of a curriculum at achieving its objectives, it is necessary to look at some aspects of students' learning. This study provided empirical evidence about learners experiencing difficulties in understanding chemical kinetics both at school and university level. This poor performance has let the Department of Basic Education in Turkey to design what it has called a law-by-law system, in which teachers are assessed by all stakeholders and not only the Principal. Educators with the lowest marks were given a chance to be re-trained because it was believed that some of the misconceptions learners have come from their educators.

The graphs are effectively utilised tools in chemistry and make it easy for people to see the relationship amongst the large datasets. Graphs are also useful in displaying the relationships that are difficult to express in numbers (Seçken & Seyhan, 2014:349). The findings of this study have shown that most learners have high levels of anxiety regarding the graphs. Most of the learners responded that they do not have any interest in graphical themes under the unit of the rate of reaction and chemical equilibrium, and that they have anxiety in drawing or interpreting graphs in the exams due to fear of making mistakes. Üce and Ceyhan (2019:203) examined the learners' misconceptions in chemical equilibrium. In their study titled *Misconception in chemistry education and practices to eliminate them* they identified the following misconceptions amongst the learners:

- While reaction is about to be at equilibrium, the velocities of forward and reverse reaction increase evenly.

- When reaction is at equilibrium, concentrations of reactants are equal to the concentrations of products.
- When reaction is at equilibrium, the concentrations of reactants and products change in time.
- When reaction is at equilibrium, the concentrations of reactants and products constantly change as they go between reaction products and reactants.
- When reaction is at equilibrium, velocity of forward and reverse reaction are equal to each other and change.
- When reaction is at equilibrium, velocities of forward and reverse reaction are not equal to each other.
- When reaction is at equilibrium, in the case when equilibrium is disturbed by the temperature increased, the velocity of reaction is higher than the velocity of reverse reaction.
- When reaction is at equilibrium, in the case when equilibrium is disturbed by the volume decreased, the velocity of reverse reaction immediately decreases; when reaction is at equilibrium again as a result of increasing temperature, the velocities of forward and reverse reaction are equal to the value at the first equilibrium.
- When reaction is at equilibrium, in the case when catalyser is added into reactor, the fact that velocities of forward and reverse reactions do not change or increase is related to reaction affinity of catalyst with forward or reverse reaction.

In this context, it can be confirmed that most learners have several misconceptions preventing them from learning chemistry content across the world.

Ahiakwo and Isiguzo (2015:112) carried out a study to probe the conception and misconceptions of senior secondary and university students in chemical kinetics in River State, Nigeria. They used two instruments to collect data for the study, namely Chemical Kinetics Calculation Problem (CKCP) and Alternative Conception Test (ACT) in chemical kinetics. The results of their study showed that most students' performance in fundamental chemical kinetics calculation was poorer than expected. Most learners could not identify the correct answers from the possible answers given. This poor

performance was attributed to the fact that some chemistry teachers perceive chemical kinetics and related concepts as difficult to teach, and that learners also perceive chemical kinetics and related concepts as abstract or difficult to learn. Teachers should worry about that poor performance of secondary students, taking into account that they have to pass into higher institutions to study chemistry and will come across chemical kinetics once again in their lifetime.

This study revealed that University students had correct conceptions and that most secondary students had misconceptions related to factors affecting the rate of reaction. It was found that the difficulties in comprehending chemical kinetics have various causes. Teachers are not conversant with the principles of chemical kinetics and are not confident in teaching it. Misunderstandings also arise because of students' misinterpretation of the terms of chemical kinetics and chemical equilibrium, and thus they cannot distinguish between how far and how fast a chemical reaction will take place. The study has also shown a larger problem in defining the term "reaction rate". The reaction rate was, in many cases, understood to be the time which reactants need to produce products; as a collision of substances A and B at a certain time; as the amount of substance that is transformed into products per unit of time at a certain temperature and concentration; or as the product of reactant and product concentrations.

Reaction rate is an important part of chemistry to grasp to comprehend subsequent chemistry topics. A study was carried out with high school learners and first year university students in Turkey in 2014, and it was found that most students encounter difficulties in reaction rate and chemical kinetics (Ahiakwo & Isiguzo, 2015:113). It was reported that most learners do not understand that reactions have the highest rate at the beginning and the lowest at the end. Many learners consider chemistry as not a fascinating subject, because the teaching and learning of chemistry do not make sense to them. The main aim of schooling is for learners to have meaningful achievement. Most learners believed that they had all these challenges in understanding chemistry because it comprised of strange knowledge grounded in a western cultural view of the world. One of the factors that attributed to high poor learning achievement was that

learners could not understand chemistry as approved by the scientific community globally, but wanted to translate it into their native language.

Meanwhile, in South Africa, Limpopo province, Capricorn South District, Zebediela cluster, Lepelle 2 circuit, Sebitja Secondary School misconceptions still prevail regarding reaction rate. This is a matter of concern to science educators, Head of Departments, and CAs; because the school has a high learner enrolment in Physical Sciences, and learners are losing a lot of marks that was unexpected. Many learners can hardly define reaction rate and cannot discuss the impact of increase or decrease in either of the factors affecting reaction rate. In the 2019 end of year examination paper, many candidates thought that temperature is the controlled variable (Q5.4). These candidates did not interpret the graph correctly (2019 DBE Diagnostic Report). It is clear from the graph that temperature is the independent variable. The conclusion that could be drawn from the graph (Q5.5) was answered well. However, several candidates stated that 'as the time increases, temperature increases', whereas the graph shows the relationship between the 'inverse of time' and 'temperature'. Many candidates did not interpret $1/t$ as the reaction rate.

The use of the collision theory to explain the conclusion from the graph (Q5.6) was not answered well. Most candidates forfeited marks by stating that at a higher temperature, molecules will have higher energy instead of higher kinetic energy, and that molecules have higher kinetic energy' instead of 'more molecules have sufficient kinetic energy. Some learners stated that more effective collisions take place' instead of 'more effective collisions per unit time and that 'effective collisions take place per unit time' instead of 'more effective collisions per unit time'.

The pass rate of learners taking Physical Sciences is currently an issue of major concern nationally and internationally (Bidi, 2016:1). The problem of poor performance in Physical Sciences is however not only restricted to South Africa, but also is apparent in the surrounding countries. Learners around the globe seem to struggle with the understanding and learning Physical Sciences. The examination results published over the past few years reflect that there is no improvement in the performance of learners in

the Physical Sciences. Moderating and analysing results for Physical Sciences since 2009, the researcher realised that learners have difficulties in understanding chemistry (Bidi, 2016:6). Learners who are unable to understand basic chemistry concepts usually label the subject as difficult. This does not only affect their performance, it also discourages them from choosing Physical Sciences as a subject at high school, thus limiting their future possibilities of a career in sciences. Science Education involves Physical Sciences, Technology, and Mathematics. It prepares learners to study science at a higher level, follow a career in science, and become scientific literate citizens (Bidi, 2016:6). The deficiency in topic content knowledge is identified as a major problem to the teaching of the topic. Due to lack of topic content knowledge, educators become less confident in their teaching and this contribute significantly to reducing learners' confidence and motivation in exploring the topic for conceptual understanding. Table 1.1 shows the achievement rates of learners from 2014 to 2020 in Physical Sciences.

Table 1.1: Achievement rates of learners In Physical Sciences from 2014 to 2020

Year	No. Wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2014	167 997	103 348	61.5	62 032	36.9
2015	193 189	113 121	58.6	69 699	36.1
2016	192 710	119 467	62.0	76 068	39.5
2017	179 561	116 862	65.1	75 736	42.2
2018	172 319	127 919	74.2	84 002	48.7
2019	164 478	124 237	75.5	85 034	51.7
2020	114 758	114 758	65.8	73 982	42.4

From Table 1.1 it can be seen that the number of learners taking Physical Sciences as a school subject drops drastically by about 20,000 every year from 2018 to 2020. The number of learners achieving quality results (40% and above) also dropped by 10 000

from 2019 to 2020. This shows some gaps in content knowledge and misconceptions held by both learners and teachers.

Figure 1.1 below depicts the percentage of overall achievement rate in Physical Sciences from 2014 to 2018. It can be seen that the overall pass rate for learners who achieved 30% and above increased from 61.5% in 2014 to 74.2% in 2018. There was also an increase in the learners who achieved 40% and higher.

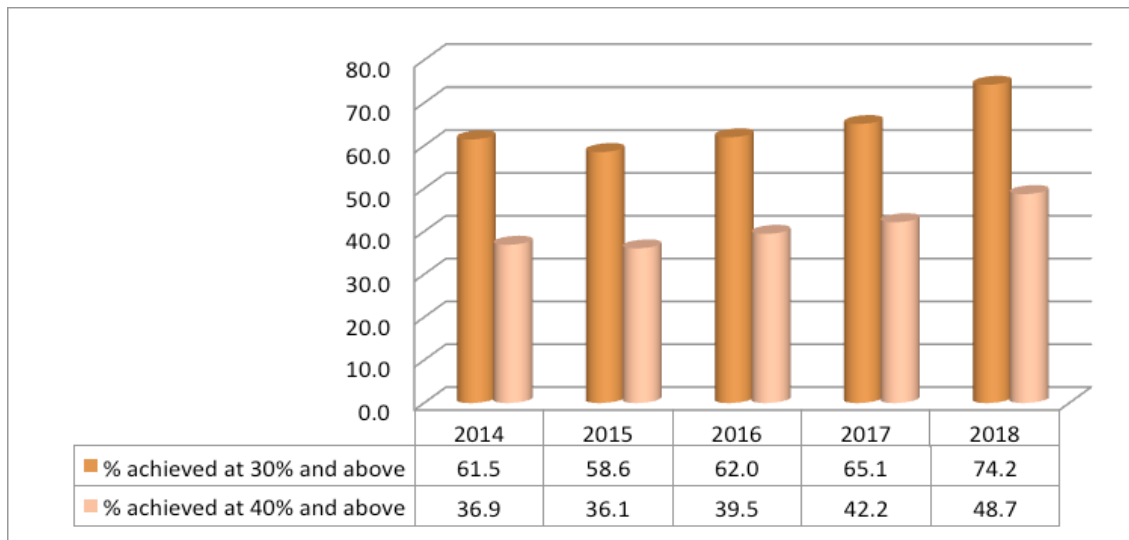


Figure 1.1: Performance distribution curves in Physical Sciences (above 30% and 40%)

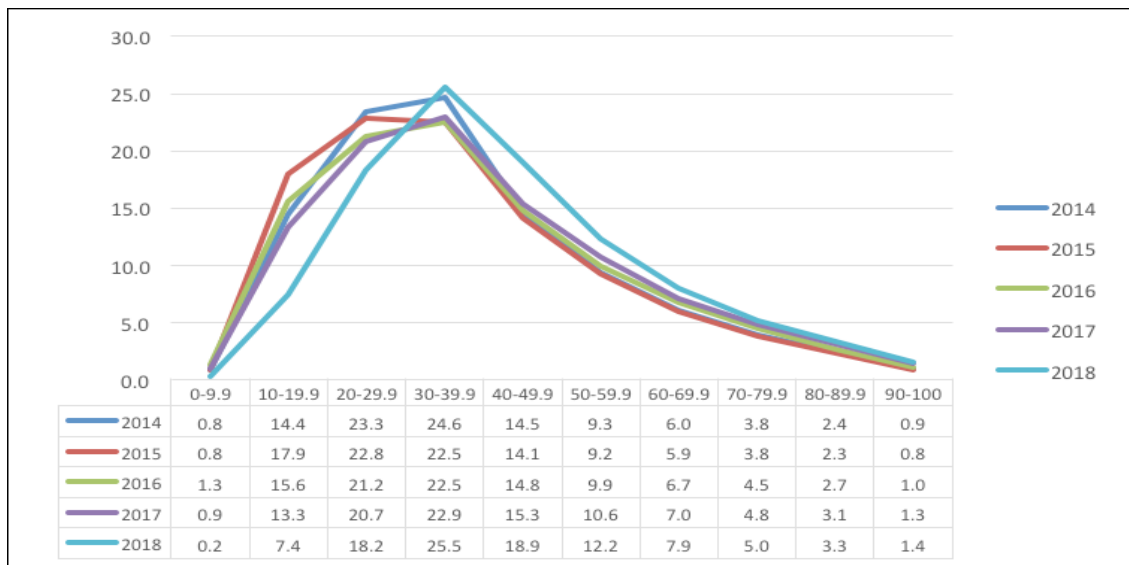


Figure 1.2: Performance distribution curves in Physical Sciences (%)

Figure 1.2 above shows the overall percentage, at 10% intervals, for learners from 2014 to 2018 in Physical Sciences.

1.3 STATEMENT OF THE PROBLEM

Learners do not have the opportunity to work in the laboratory because our schools do not have the facilities, and as a result the learners conclude that chemistry is a disintegrated discipline, irrelevant, and not useful facts. Bidi (2016:6) indicated that it is not easy for teachers to perform experiments. Misconceptions result from the students' attempts to understand their previous experiences resulting from their interaction with their environment, and it should be taken into account in educational practices to design appropriate instructional strategies that will urge their evolution into more scientific-academic concepts (Basheer et al., 2018:3110). The meaning cannot be understood clearly as it is based on prior knowledge. Errors in understanding the concept can be regarded as a misconception (Fahmi & Irhasyuarna, 2017:54). With regard to reaction rate, learners are unable to comprehend the different concepts: enthalpy, entropy, chemical change, activation energy, and factors affecting reaction rate. Science misconceptions are persistent, resistant to change, and deeply rooted in some concepts.

As a result of these misconceptions learners do not understand the concepts related to reaction rate and hence fail (Soeharto et al., 2019:248). This study will be very helpful to the Grade 12 learners, because it aims at identifying the origins and the types of misconceptions that learners have, and try to resolve the misconceptions. Bidi (2016:1) has shown that it will be appropriate to explore new strategies and ways to enable learners to achieve the desired outcomes at a higher level in Physical Sciences. Misconceptions are resistant and make it difficult for learners to acquire new knowledge once developed in the learners' minds. These misconceptions might have developed as learners themselves build or construct their own knowledge (Karsli & Ayas, 2014: 664). The pre-existing knowledge and the formal instructions might have incorrectly linked, and resulted in misconceptions.

In 2018 final examination paper, most learners could not apply Le Chatelier's Principle (LCP) to a situation where the pressure of a gas increased due to a decrease in volume (DBE diagnostic report, 2018:169). Many learners missed the effect of an increase in pressure due to a decrease in volume of a gas on the rate of forward and reverse reactions. Many learners defined rate of reaction as the extent of a reaction and that learners sometimes apply the LCP to rate of reaction concepts (Karsli & Ayas, 2014:664). The learners usually find it difficult to distinguish between time and rate of a chemical reaction. Majority of the learners obtained marks for the interpretation of the Boltzmann distribution curves, and failed to give the correct reasons for their answers. In the 2019 final examinations, many learners interpreted the graph parallel to the x-axis as representing a reaction that has reached equilibrium. Learners did not know that the gradient of the graph represented reaction rate (DBE diagnostic report, 2019:226). Most of the learners selected one of the headings of the columns in the table that was given.

According to Ahiakwo and Isiguzo (2015:114), learners' construct of an idea or concept could be correct or incorrect. A great deal of research studies on chemical reaction rate have been done in the last few years, but have given most attention on the relationships between learners' prior knowledge before initiating formal education and the scientific knowledge. Different teaching and learning models have been put in place to facilitate conceptual change (Ozdilek, Okumus & Doymus, 2018:945). It is imperative to go a little deeper and change the principles in which learners' conceptions are framed, and from which they have developed. Bidi (2016:5) has undertaken a study to investigate the use of a Conceptual Change Approach as a teaching strategy to improve learners' understanding of Chemical Change in Physical Sciences.

School science education should instruct learners in an acceptable manner to achieve its desired objectives, but it usually fails to do so because of the reasons associated with the complexity of the content (Ahiakwo et al., 2015:113). This failure at a later stage becomes a mismatch between what the learners can learn and what curricula instruct teachers to teach them. This is attributed to the fact that science education has not been using appropriate teaching methodologies to challenge the learners' alternative conceptions. Karsli and Ayas (2014:664) showed that the resistance of

learners' learning difficulties in reaction rate are associated with their teachers' content knowledge. Gurmu (2018:195) indicated that student teachers and in-service science teachers coming from or belonging to different countries or regions have some conceptual difficulties.

It is common evidence that content knowledge is not only an imperative part of teachers' professional knowledge on its own, it also forms a part of the teachers' pedagogical content knowledge (Ejidike & Oyelana, 2015:207). It becomes the responsibility of the teachers to see to it that they master the content and that they are able to present the lessons fruitfully, using all teaching aids and materials around them. Hanson (2020:73) showed teachers' inabilities to translate abstract concepts into concrete concepts for the learners. The fundamentals of constructivism and constructivist science teacher education should be taken into consideration to identify teachers' conceptions, so that teacher training can start from the teachers' current knowledge, experience, and assist them to overcome their conceptual challenges so that they are able to teach what are expected and in a proper manner. According to Ortiz (2019:34), the pedagogical content knowledge is believed to be the central component of the teachers' pedagogy and comprehension of science content in such a way that it influences their teaching to best engender learners' science learning for understanding.

Teachers offer the learners distinctive learning opportunities so that they are able to construct their knowledge properly in the learning process (Kolomuç & Tekin, 2015:85). Learners are encouraged to construct their knowledge actively by taking part in different learning activities, or by making use of a variety of teaching and learning materials at their disposal. In learning settings, learners can correctly construct knowledge if their teachers set good examples that include problem-solving processes, explanations, and by relating concepts to each other. According to Marumure (2014:4), different teaching strategies such as laboratory activities, analogy assisted texts, computer assisted teaching, and cooperative learning can be used to effectively arouse learners' interests in chemistry (reaction rate) and increase their understanding of the subject content. Cooperative learning requires learners to work together in small groups to support each

other in understanding the content and accomplish the desired goal (Kırık & Boz, 2012:221).

Prominent factors contributing to the persistence of learners' misconceptions and poor performance in chemistry are:

- Lack of infrastructures and teaching materials, and lack of laboratories (Ejidike & Oyelana, 2015:605).
- Ineffective teaching methods adopted by the chemistry teacher.
- Lack of professionally qualified teachers.
- Wording and style can lead to misconceptions and it becomes challenging to learn the language or wording of chemistry (Üce & Ceyhan, 2019:202).
- Lack of organised subject content, nature, and ways of subject delivery (Gurmu, 2018:199).
- Poor mathematics background. In an attempt to address the problems highlighted above, some research has been carried out. These include team teaching approach, formative testing with remediation, algorithms strategy in solving chemical arithmetic problems, and concept mapping.

All these strategies gave little improvement on the conventional teaching method, which is being used in our secondary schools.

Okumus, Koc and Doymus (2019:157) indicated that cooperative learning is a suitable strategy to deal with the misconceptions and improve learners' conceptual understanding of abstract concepts. The learners will be experimenting for themselves in groups under the supervision of the teacher. Therefore, the learners will be provided with opportunities to increase their efforts to achieve and to improve their interpersonal relationships: positive interdependence, social skills, and group processing (Kolomuç & Tekin, 2015:85). To achieve the desired objective of effective teaching of chemistry in

secondary schools, operational chemistry laboratory equipment has to be provided but it is dish-eating to note that most of our schools do not have functional laboratories.

1.4 RESEARCH QUESTIONS

1.4.1 Main research question

To what extent, if any, do misconceptions affect the conceptual learning abilities of the learners?

1.4.2 Sub research questions

- What misconceptions do the learners have with regard to reaction rate?
- How do these misconceptions originate?
- What are the effects of these misconceptions on learners' understanding of rate of chemical reactions?
- What are the general performances of learners with regard to reaction rate?

1.4.3 Objectives of the study

- To identify the source of misconceptions in learners' memories.
- To identify learners' misconceptions with regard to reaction rate.
- To examine the effects of these misconceptions on learners' understanding of the rate of chemical reactions.
- To assess the general performance of learners with regard to reaction rate.

Most of our schools do not have laboratories and subsequently learners think and believe that chemistry is a body of unrelated useless facts and skills. Science laboratories are non-functional because there is no equipment (Bidi, 2016:5). Chemistry education enables learners to study chemistry post Grade 12, thereby giving them the opportunity to be well prepared for a career in sciences, and becoming scientific literate citizens. Ejidike and Oyelana (2015:606) have shown that a lot of concern has been indicated about the inadequacy of science laboratories in South Africa. Marumure (2014:6) has shown that improvement in the quality of teaching is required, which could

improve learners' performance in chemistry. National Research Council stated that the primary role of misconceptions in science is that they are barriers for students to learn science because in many cases, misconceptions can hinder students from developing correct ideas to use as the initial insight for advanced learning.

These misconceptions normally arise as a discord between the teacher's instructions and the learners' prior knowledge. Üce and Ceyhan (2019:202) have shown that learners come into a learning environment with some thoughts and concepts that are scientifically incorrect. The formal knowledge that the learners acquire from formal learning setting interacts with the learners' prior knowledge, and result in a diverse set of unintended outcomes. Ahiakwo and Isiguzo (2015:114) have shown that it is clearly the concern of the teacher to correct the misconceptions. According to the constructivist learning method, learners try to interpret the new information they encounter from their former prior knowledge (Üce & Ceyhan, 2019:203). It is necessary for learners to construct the correct understanding of the chemistry concepts at high school level, so that they can gain the necessary basic ideas on which they can build the additional knowledge required to comprehend advanced concepts at a later stage. Misconceptions do have an influence in the conceptual ability of the learners.

1.5 SIGNIFICANCE OF THE STUDY

The purpose of this study is to examine the high school learners' misconceptions and views with regard to reaction rate. Data will be collected from the learners through a Reaction Rate Concept Test (RRCT), which will be carefully developed looking at concepts and areas in which learners are struggling most. Karsli and Ayas (2014:668) indicated that remedying student-teachers' alternative conceptions would be worthwhile to prevent teacher-based alternative conceptions. Even if it is challenging to study, it is recognised as a choice for an appropriate career because technological advancements are supported by the mastery of science (Maison et al., 2019:17). Misconceptions hinder the learning progress of the learners, and deprive them the opportunities to follow better career choices in sciences. There is a belief that these misconceptions can

be identified, dealt with properly, and gradually replaced with scientific ones (Kolomuç & Tekin, 2015:85).

This research study will be very helpful and useful to the Grade 12 learners for this year and in the future teachings; because it aims at identifying the origins and the types of misconceptions learners have regarding reaction rate, and try to resolve misconceptions. It was found that one of the main sources of misunderstanding chemical reactions comes from mixing concepts of kinetics and thermodynamics (Koretsky, 2020:107). Once the misconceptions are detected and addressed or fixed, the learners' understanding of chemistry concepts will increase and learners' achievement will improve significantly. Marumure (2014:1) has shown that reaction rate research have been conducted all aiming at improving the quality of chemical education. According to Basheer et al. (2018:3111), learners should be introduced at an early stage of education to learning strategies, so that learners' misconceptions are discovered earlier in their learning, resulting in the necessary steps taken to remedy the misconceptions. The learners are encouraged to work in groups to ensure that they share ideas and have a common understanding of the concepts.

Chemistry educators will benefit from research findings and recommendations for teaching reaction rate as all the problems will be documented. Educators may use these as a guide during lesson preparation and lesson presentation. When reference is made to documented problems and the prospects, as well as implementing the recommendations, educator effectiveness will be improved (Marumure, 2014:2). The hard-working and the less hard-working educators will benefit more since reaction rate is an area where many learners present several alternative concepts. In addition, the difficulties in defining effective science teaching are embedded in the numerous characteristics and roles of the classroom teacher. Effective science teaching requires an understanding of the subject matter, which needs to be taught in several engaging ways (Ortiz, 2019:34). Hard-working educators will know what to expect when they start teaching the topic, and the less hard-working educators will improve their teaching by trying what other educators are doing to reduce the formation of alternative concepts. Marumure (2014:6) has shown improvement in quality of teaching, which could improve

learners' performance in chemical equilibrium and chemistry in general at the FET band.

1.6 RATIONALE FOR THE STUDY

The study is significant because it attempts to root out and resolve the learners' alternative concepts regarding reaction rate. In this study the conceptual change approach will be used to identify the misconceptions learners have. Koretsky (2020:106) described four conditions which must be fulfilled for a conceptual change to occur. Once misconceptions can be addressed, learners' interests in studying chemistry post-secondary education will increase, and as a result, more learners will pursue appropriate careers involving chemistry (Maison et al., 2019:17). Industrial processes such as Ostwald, Contact, and Haber involve the same factors (concentration, temperature, pressure, and catalyst), which learners learn in Grade 12. Success in studying chemistry requires students' sound reasoning skills, fundamental scientific knowledge, and ability to work with scientific knowledge. Lessons in chemistry had become a burden to students, since these lessons require lots of imaginary and abstract processes, which are non-tangible and non-visual in context (Ortiz, 2019:34).

Practical skills should be given more attention in schools (DBE diagnostic report, 2019:227). Learners have a poor understanding of skills such as identifying variables and interpreting the graphs correctly and giving reasons. Teachers should ensure that learners know how to differentiate between the independent variable (a factor that is changed during the experiment), the dependent variable (a factor affected by the change made), and the controlled variable (a factor that is kept constant). Emphasis should also be placed on the difference between the reversible and non-reversible reactions. Reversible reactions can reach equilibrium, whilst non-reversible reactions take place in one direction and cannot reach equilibrium. When teaching reaction rate calculations, it should be emphasised that the formula is not available on the data sheet. Teachers should ensure that learners know the different scenarios, namely change in surface area, change in temperature, change in concentration, and addition of a catalyst

that should be explained in terms of the collision theory. Stoichiometry needs more attention in class (DBE diagnostic report, 2019:221; DBE diagnostic report, 2020:227).

Learners struggle to use ratios correctly and are very uncertain when selecting formulae for specific calculations. Content and methodology training for teachers on the application of LCP will assist inexperienced teachers to teach this topic (DBE diagnostic report, 2018:170; DBE diagnostic report, 2019:223). Experienced teachers can also share methodology in the teaching of the topic with others. Learners struggle to express themselves when explaining in terms of LCP, and they should be exposed to more exercises to practice such explanations. This problem seemed to have entrenched itself in learners' minds, as it prevails every year. In 2020 end of year examinations paper, very few learners obtained full marks for the stoichiometric calculations, and many learners did not interpret the graph correctly and thought that the temperature is the controlled variable (DBE diagnostic report, 2020:226).

1.7 DEFINITIONS OF CONCEPTS

Curriculum advisors: Specific subject specialist who support school teachers by developing and improving the instructional materials for lessons.

Reaction rate: Speed at which reactants are converted into products.

Enthalpy: Total heat content of a system or internal energy of a system including the product of pressure and volume.

Entropy: Degree of disorder or randomness of the particles in the chemical system.

Chemical change: Occurs when a substance combines with another to form a new substance

Activation energy: Minimum energy required for a chemical reaction to take place.

Concentration: amount of substance per given volume of solution.

Catalyst: A substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Chemical Kinematics: The branch of physical chemistry that is concerned with understanding the rates of chemical reaction.

Chemical Reaction: A process that involves rearrangement of the molecular or ionic structure of a substance as distinct from a change in physical form or a nuclear reaction.

Conceptions: Generally accepted scientific terms.

Misconceptions: Alternative concepts that is parallel to or inconsistent with scientific concepts.

Mixed Method Approach: Multiple methods for conducting research that collecting, analysing, and integrating quantitative and qualitative research.

Conceptual Change: Process whereby concepts and relationships between them change over the course of time.

Paradigm Shift: Fundamental change in approach or underlying assumptions.

1.8 SUMMARY OF CHAPTER

In this chapter, the focus was on problem statement, background of the study, research question, and significance of the study. The next chapter will pay more attention on theoretical framework and literature review. Various literatures were reviewed to establish the aims of the research and to understand the impact of and the origins of the misconceptions regarding reaction rate. The chapter will be presented in the following sub-headings: construction of knowledge, learning of reaction rate as a topic, teaching of reaction rate as a topic, training for chemistry education, and summary of review.

CHAPTER 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

There has been a concern raised by CAs, in a meeting guided by the diagnostic report for 2019 end of year examinations that most learners did not do well in chemistry, simply because the learners held some misconceptions regarding chemical reaction rate and the related graphs. DBE Diagnostic Report (2020:226) outlined that most candidates did not know that the gradient of the graph represented reaction rate (Q5.2.1). The reaction rate is one of the most difficult concepts for learners (Hakimah, Muchson, Herunata, Permatasari & Santoso, 2021:1). It was emphasised that reaction rate is the fundamental chapter in chemistry that forms a basis for subsequent topics. If learners can have a better understanding of concepts regarding reaction rate, they will obviously improve their academic performance and start to see chemistry as an interesting school subject to pursue as a career, and not as an abstract and complex course. Chemistry has been described as a difficult subject by learners of different ages in different countries, as it has a lot of abstract concepts (Karsli & Ayas, 2014:664). These learners' high failure rate triggered my interests in pursuing studies in reaction rate.

A conceptual understanding goes beyond knowing facts and labels. Bidi (2016:21) defined concepts as mental categories for objects or events that are stored in the brain in a network reflecting the relationship with other concepts, known as a conceptual framework. Reasonably, conceptual understanding becomes meaningful only when it can be used to explain or to explore new situations. Turanyi and Toth (2014:117) have shown that learning theory highlighted that learning is an active process in which the learner takes information from the environment and constructs personal interpretations and meanings. Every individual creates concepts according to his or her unique learning experience and maturational pattern (Bidi, 2016:21).

2.2 THEORETICAL FRAMEWORK

According to Bidi (2016:19), a framework within research is a tool intended to assist a researcher to develop awareness and understanding of the situation under enquiry and to communicate. The researcher needs to prepare a framework for the conceptual aspects of the study, to explain the different methods and strategies that should be utilised in conducting a research. Marumure (2014:61) has shown in his study that most of the educators advocated a strategy for conceptual change. The conceptual framework of the study is a structure that can support a theory of the research work, and it presents the theory which clarifies why the challenges/problems under study exist. The Conceptual Change Theory is one of the effective methods for dealing with misconceptions and for understanding concepts (Bidi, 2016:27). The researcher in this case has formulated the conceptual framework on the necessity to teach reaction rate as an area of specialisation.

The theoretical framework of this study is an everlasting conceptual change practice of teaching chemistry education in schools, in particular reaction rate. Karsli and Ayas (2014:664) used one conceptual change method and/or technique such as group discussion, and simple activities, computer based learning, hands-on laboratory, concept change texts supported by analogies, and research based instruction. But in order to achieve conceptual change, learners' interests in chemistry must be stimulated; learners are encouraged to commit mistakes and express their minds during the teaching and learning processes. Koretsky (2020:106) proposed that virtual laboratories can serve as an effective medium for creating cognitive conflict that leads to improved conceptual understanding in students. In addition, the learners' attitudes towards the subject must also be redirected by presenting them with different appropriate career choices that are on the market, and modelling the subject content (Maison et al., 2019:17).

Teachers should change their approach and use different teaching methods and techniques to accommodate all learners, and ensure that all learners' challenges are addressed immediately, with relevant information to avoid development of

misconceptions. Üce and Ceyhan (2019:203) advocated for a change in the teaching methods applied in the science class. The notion of effective teaching practice is based on strategies that promote conceptual change and equip learners with skills on learning and making meaning out of their learning, which is part of the constructivist view of learning and produce scientifically literate citizens (Koretsky, 2020:106). It is through effective teaching practices that learners are engaged actively in the learning process that promotes the achievement of intended objectives. The overarching goal of science education today should be to educate scientists who will be at home in society, and to educate a society that will be at home with science (Vergis, 2017:7).

2.3 CONCEPTUAL APPLICATION

The conceptual change theory was used in the classroom context by giving learners a lengthy pre-test based on reaction rate. After marking the activity, the learners were given feedback immediately and discussed only questions which most learners had wrong. There was a first administration of the tests, followed by a second administration of the tests after two weeks (Ahiakwo & Isiguzo, 2015:7). But this required questions designed properly by experts who happen to know the tricks in the topic. (Ahiakwo & Isiguzo, 2015:7) posited that the two instruments were given to three doctoral students in chemical education to check, consider the level of the learner, content, and the answers to the questions. Bidi (2016:118) found that by giving learners a post-test after the intervention, there was a statistically significant difference between learners' pre-test (26.7%) and post-test (65.1%) scores.

In order to achieve conceptual change, learners' enthusiasm and interests in chemistry must be stimulated by posing fascinating questions to them. Vergis (2017:4) has shown that learners' interest and performance in mathematics and science deteriorate through elementary and secondary school. In addition to this, the learners' attitudes towards the subject must also be redirected by exposing them to different career choices that are on the market, and modelling the subject content. A strong indicator of the pupils' attitude is their choice of subjects. The proportion of post-secondary students taking science, particularly physical science, remains a cause for concern (Vergis, 201:19). Conceptual

change model is necessary to increase the status of a conception by providing conceptual change conditions (Kırık & Boz, 2012::222).

2.4 LITERATURE REVIEW

A literature review is a survey of scholarly sources on a specific topic. It provides an overview of current knowledge, allowing the reader to identify relevant theories, methods, and gaps in the existing research. After sample literatures were read, misconceptions and the methods to remove them have been examined, a few literature works were chosen for the study (Üce & Ceyhan, 2019:203). Karsli and Ayas (2014:664) have shown that literature is investigated, analysed, and it is observed that there has been a positive relationship between students' conceptual development and scientific process skills. A literature review or narrative review is a scholarly paper that presents the current knowledge, including substantive findings, and theoretical and methodological contributions to a particular topic. A research study requires thorough literature analysis (Üce & Ceyhan, 2019:203). Literature reviews are secondary sources and do not report new or original experimental work.

2.4.1 Construction of knowledge

Bidi (2016:24) has shown that individuals are not simply passive learners but make sense of new information in terms of their previous ideas and experiences. Karsli and Ayas (2014:664) have examined secondary school learners and undergraduate students' conceptual understanding of chemical kinetics. In his study, though, most of the students knew the factors affecting the rate of reaction (temperature, surface area, catalyst, and concentration) and many of them did not agree that volume or pressure are factors affecting the rate of chemical reaction in a gas phase. Some students used the terms of concentration and number of moles interchangeably. A misconception held by most learners is that the rate of reaction is directly proportional to the concentration of reactants, and most learners cannot differentiate between reaction rate and reaction time (Fahmi & Irhasyuarna, 2017:55).

Ahiakwo and Isiguzo (2015:113) have shown that most learners are unable to differentiate reaction rate and reaction time in understanding that the reactions had the highest rate of the beginning of the reaction and the lowest at the end; they confuse the chemical kinetic concepts with the thermodynamic concepts. The learner's interpretations are influenced not only by the external environment, but are also shaped by the learner's prior knowledge and experiences. According to Sari et al. (2019:2), misconceptions result from the interaction between learners and environments. Misconceptions on reaction rate seem to have rooted in the learners' minds long before and have been problematic to the learners' progress in the chemistry curriculum, especially in the rate of reaction. Evagorou, Erduran and Mäntylä (2015:4) identified the possible sources of learners' misconceptions as school teaching, outside school teaching, every day experiences, social environment, and intuition. These misconceptions or alternative conceptions are poorly organised resources and usually play an important role during learning. Learners construct knowledge by 'modelling' new information onto already existing schema (Hanson, 2020:72). This implies that whatever students already know, whether wrong or right, affects the gain of new knowledge. There is therefore the need to be cautious when new schema has to be constructed.

The development of some specific science concepts is complicated and it is of utmost importance to take into account the value of designing instructions to repair the learners' pre-existing experiences (Kolomuç & Tekin, 2015:771). The misconceptions brought by learners into the formal learning situation cut across gender, age, and cultural boundaries, and their origin is learners' personal experiences gained through observation, culture, peer, perception, language, instructional materials, and explanations (Kaya & Geban, 2012:37). This simply indicates that rate of reaction is difficult for that learners because of the inadequate teaching, stemming from inadequate knowledge by the teachers, normal language which tends to confuse and undo teaching, and every day experience of the material world. Taştan and Boz (2014:168) indicated that one of the main reasons for this difficulty is the fact that learners are insufficiently equipped with the correct science concepts, and as a result of that, they are unable to distinguish between different roles in different contexts.

Bozkoyun (2014:30) has shown that many learners come to the class with their own conceptions of natural phenomena that are not consistent with scientific explanation. Misconceptions or conceptual difficulties of learners are potential barrier or risk to academic success of learners in science. According to Kolomuç and Tekin (2015:85), teachers offer a variety of learning opportunities so that their learners can construct knowledge properly during the learning process. They help the learners to construct their knowledge actively by encouraging them to participate in various learning activities or making use of different learning materials. According to Kirik and Boz (2012:6), children learn through their interactions. Problem solving processes and explanations teachers used set an example of learning and present knowledge for learners with other people. They internalise skills and knowledge experienced during these interactions and ultimately they use those internalised skills and knowledge to shape their own behaviours.

Learners often construct their own meaning that they see in their environment. The meaning can't be understood clearly yet based on its prior knowledge, so the meaning that learners constructed may be true or false. Errors in understanding (construction) the concept briefly can be regarded as a misconception (Fahmi & Irhasyuarna, 2017:54). Another opinion also defines misconceptions as a conviction or belief that is not in accordance with generally accepted explanation and proved to be true of a phenomenon (Taylor & Kowalski, 2015:63). Teachers should carefully and thoroughly give information (academic or non-academic), not to be ambiguous, incomplete, and give a space for misunderstanding. It is important for teachers to understand the misconceptions first. An understanding of the misconceptions can be constructed by reading some of the relevant literature, to avoid the language barrier, it is important to know the other terms of the misconceptions. Turanyi and Toth (2014:113) mentioned some of the terms used in some of the literature that is equivalent to misconceptions, such as alternative conceptions, alternative frameworks, spontaneous knowledge, and so forth. With this knowledge, it is hoped for the future that learners' misconceptions can be detected earlier and then corrected.

Fahmi and Irhasyuarna (2017:54) posit that one of the things that is concerning in misconceptions is when someone knows a misconception, but he/she did not realise it was happening. It needs hard work to correct misconceptions, not only the reconstruction of the understanding of learners (notifying is less effective), but also had to look for the causes of these misconceptions (requires detector). According to Taştan and Boz (2014:168), one of the major reasons for the difficulties at the junior level is the fact that learners sometimes are insufficiently equipped with the necessary science concepts and become unable to differentiate among the different roles in different contexts. This means that it is important to understand it is not easy to eliminate misconceptions by applying conventional teaching methods. The main characteristics of misconceptions are that students construct alternative definitions for the concepts studied; many of them believe in them as scientific fact, and it is very hard to change such incorrect beliefs (Basheer et al., 2018:3110).

The misconceptions that are found on these items are "the reaction rate may not be deductible and definition of reaction rate is the number of reactions that take place per unit time". Because the definition of the rate that often written in the book is a change in the concentration of reactants or products per unit of time or changes in unit time and also the words "rate is a measure of how fast or slow a reaction to take place" or "rate tells you how fast or how slow a process is happening". According to Fahmi and Irhasyuarna (2017:56), misconceptions are categorised by cause: learners' associative thinking of the word and the rate of change. Learners rarely connect the words used in the reaction rate, which is "change the number" which can be interpreted correctly for the "reduction" or "extra" components of a substance. The word number of reactions that take place frequently encountered learners, when the process of recalling the words often associated with the reaction products are considered. Learners also understand if the reactant concentration is high then the number of particles is high. But students do not understand and cannot explain why high concentrations can lead to faster reaction high (Sari et al., 2019:4).

2.4.2 Learning about reaction rate as a topic

From the results of thousands of studies reported, it was shown that individuals are not simply passive learners but make sense of new information in terms of their previous ideas and experiences (Bidi, 2016:19). One outcome of such learning is that learners' knowledge is not consistent with the scientists' science, in other words, the pre-knowledge which learners bring to the classroom that make sense to them based on their daily life experiences may not match the science context and therefore may be wrong. Ahiakwo and Isiguzo (2015:113) has shown that most learners are unable to differentiate reaction rate and reaction time in understanding that the reactions had the highest rate of the beginning of the reaction and the lowest at the end; they confuse the chemical kinetic concepts with the thermodynamic concepts. These conceptions are referred to as children's science or misconceptions or alternative conceptions dependent on the author's philosophical world. Wardah, Wiyarsi and Prodjosantoso (2020:2) also confirmed that both the high school and university students had various misconceptions about the rate of reaction. Research further indicated that these views are often firmly held, are resistant to change, and present difficult challenges for teachers of science.

Kirik and Boz (2012:222) indicated that learning is a social event and learners should be provided with a conducive learning environment to work with their peers that can also allow their individual differences. They claimed that sociocultural factors such as collaboration and discussions were found to influence conceptual change, because discussions make learners aware of the need to change their conceptions. Learning in science entails more than just adding new concepts to knowledge (Bozkoyun, 2018:4). Science learning often requires realignment in thinking and construction of new ideas that may sometimes be in conflict with earlier or older ideas. According to Bidi (2016:45), when learners want to understand new material they must use the new knowledge and combine it with their existing knowledge. The main function of constructivism is to organise knowledge by using previous experiences or understandings.

Chemistry education is different from other subjects. Koretsky (2020:107) indicated that chemistry education exists in three different but intertwined levels, which cannot be comprehended at the same time. These levels are macroscopic, microscopic, and representational. In macroscopic level learners are expected to observe the situation, while in microscopic level learners are expected to learn more about the movement or arrangement of particles. Having understood the two levels, learners can now attach scientific implication in the representational level. Reaction rate and chemical equilibrium, which are normally called Chemical change, contributes 21% of the total marks of the National Senior Certificate (NSC) examination. Therefore, it means it directly contributes 63 marks out of the 300 marks of the examinations (2019 June exam paper, 2019 trial exam paper, and 2019 November exam paper). For instance, Ahiakwo and Isiguzo (2015:113) revealed that students have a problem in understanding the relationship between experimental results and the rate of reaction. Even if the students were using their knowledge on algorithms to solve these problems, many of them could not use the given experimental results to write the rate law. Teachers should take on the role of a “coach, guide, consultant, mentor or co-learner” rather than functioning as a “talking head” (Vergis, 2017:6).

Vergis (2017:4) indicated that the state of science education in schools has been the topic of much discussion during the last two decades because there were two issues of particular concern to science educators, namely the pupils’ attitudes towards science as a school subject, and the pupils’ understanding of the ideas of science. A strong indicator of the pupils’ attitude is their choice of subjects. The proportion of post-secondary students taking science, particularly physical science, remains a cause for concern. Ozdilek et al. (2018:945) indicated that science is one of the most difficult lessons in general to learn, because of the abstract subjects and concepts it contains. Research has been carried out in the fields of physics and chemistry education in order to test effective science learning and to eliminate the misconceptions about the subjects (Fahmi & Irhasyuarna, 2017:54).

According to Siswaningsih and Widasmara (2019:1), understanding of chemistry concepts is very difficult for most learners. Rate of reaction and the factors affecting rate

of reaction are important concepts in basic chemistry. Chemistry is a subject based on concepts, many of which are abstract and are therefore hard to grasp and learn, especially when the students are put in a position to believe without seeing. Misconceptions that tend to occur in chemistry can cause students to be less successful in applying these concepts to new situations suitable, and in turn students may fail to learn the concepts of chemistry. Several studies have found that misconceptions have occurred in some chemical concepts such as reaction rate (Pikoli, 2020:2). Chemical kinetics is a vital discipline to grasp in order to comprehend a chemical change as a whole. It also provides vital skills sought for by physical chemists in particular and its comprehension is highly desirable.

Ahiakwo and Isiguzo (2015:113) indicated that one stage in science curriculum development that is relevant in this discourse is the implementation of an added portion of the curriculum arising from the growth/ learners' achievement. This is where teaching and learning is done. The impact of teaching is evidenced in the performance of the learners. It is thus suspected that there could be a link between the growth in a science education project and the performance of science students. Ozdilek et al. (2018:945) indicated that science is one of the most difficult lessons in general to learn because of the abstract subjects and concepts it contains. Fahmi and Irhasyuarna (2017:54) have shown that research have been carried out in chemistry education to test effective science learning, and to eliminate the misconceptions about the subjects. It is also possible to use the kinetic model to evaluate the growth of a science education project considering the performance of the students after ascertaining their entries.

During the learning process, learners should make an effort and be attentive, and they should be encouraged to be actively involved in the course of action instead of being passive (Kırık & Boz, 2012:222). Learning in science entails more than just adding new concepts to knowledge. According to Kirik and Boz (2012:4), science learning often requires realignment in thinking and construction of new ideas that may be in conflict with earlier ideas. Learners substitute old ways of thinking and construct new ways of thinking that are based in new information they find useful. The other results of the research have shown that students are not interested in learning chemistry and tend to

use memorisation methods without understanding concepts. Chemistry problems can be better solved by students if students understand their basic chemical concepts first (Wardah et al. 2020:1).

Kaya and Geban (2012:219) identified the following misconceptions as the major problems hindering the success of learners' achievement in reaction rate at elementary level and beyond. He discovered that most learners defined reaction rate as the time between the beginning and finishing of a reaction, and that reaction rate is the number of atoms colliding in a unit time. He emphasised that if these misconceptions can be dealt with accordingly learners' success in chemistry lessons would improve against the persistent alternative conceptions. Kaya and Geban (2012:219) have shown that one of the misconceptions is that for a chemical reaction to occur, the colliding particles should be in gas phase, and all collisions in gas phases produce a chemical reaction. A few groups of learners have shown that when concentration increases, surface area increases; thus, reaction rate increases, reaction rate is independent of reactants' concentration and while a reaction occurs, concentration of products increases in time; thus, reaction rate increases.

Most learners have shown misconceptions in that when temperature increases, rate of reaction decreases and change in temperature does not affect reaction rate (Kaya & Geban, 2012:219). Some of the learners indicated that when particle size of reactant is decreased, its volume is decreased and therefore rate of reaction increases, because substances with big particle size move slower than those with small particle size, their reaction rate decreases and catalyst is an intermediate substance which participates in a reaction as a reactant but gets out without affecting the reaction (Kaya & Geban, 2012:219). According to DBE Diagnostic Report (2019: 226) most learners defined catalyst as a substance which is formed and then consumed during a reaction the substance which participates in a reaction and gets out is the same substance as intermediate substance.

Alternative conceptions are not unusual. They are normal part of the learning process and learners quite naturally form ideas from their everyday experiences, but obviously

not all the ideas they develop are correct with respect to the most current evidence and scholarship in a given discipline. These misconceptions impede learning. According to Ahiakwo and Isiguzo (2015:113), studies have reported that students perceive chemical kinetics and related concepts difficult to learn, and that some chemistry educators were not comfortable in teaching chemical change. Learners should be dissatisfied with their existing ideas and the new knowledge presented has to be intelligible, plausible, and fruitful. Kirik and Boz (2012:222) have stated that making students aware of the inconsistencies between their conceptions and the scientifically accepted knowledge is essential to promote conceptual change. Some scientific concepts are too difficult for students to understand. This can occur for a variety of reasons, but one of the primary reasons can be that everyday experiences can provide evidence that supports incorrect assumptions. Kolomuç and Tekin (2015:84) argued that individuals generate knowledge and meaning by interacting with the environment around them.

Soeharto et al. (2019:248) have shown that conceptual misunderstandings are scientific information that arises when students construct their own confusing and wrong ideas, based on the correct scientific concepts, for example, students find it challenging to understand the concept of usual style because they only understand that style is only a push and a pull. Vernacular misconceptions are mistakes arising from the use of words in everyday life that have different meanings based on scientific knowledge. Gurmur (2018:194) stated that some researchers suspected that college students, university students, and even teachers could have misconceptions, not only about the advanced chemical concepts, but also about those very basic chemical concepts from the very beginning, which they have learnt in primary education many years before. It was found that these early misconceptions about basic and fundamental chemistry concepts have been identified in primary, secondary, and tertiary education. Concepts in chemistry were hierarchically built from basic (Jusniar, Effendy, Budiasih & Sutrisno, 2020:1405). Therefore, students' mastery of prerequisite concepts would be an important variable in chemistry learning, which can either help or hinder their understanding of the next related concepts.

The law of the conservation of mass is basic for our understanding of the world, and for understanding that energy is neither created nor disappears. If one mixes a large quantity of different materials inside a closed system, the total mass is the same before and after the chemical reaction, irrespective of the amount of matter (even if the original materials are combined or separated). Middle-school students must therefore learn that physical and chemical changes in a closed system do not affect the amount of mass. Basheer et al. (2018:3110) have found that students have difficulty understanding the conservation of mass and chemical reactions inside a closed system. It is evident from this that the development of a particulate model of matter, which includes an understanding of the nature and spacing of the constituent particles and how these are related to the macroscopic properties of substance, poses significant difficulties for most of the students.

Research proposed that students' conceptions of matter progress from a homologous substances' view through substance units and particle units before achieving a conception based on systems of particles. Ahiakwo and Isiguzo (2015:125) stated that most students could not specify the correct unit of measurement involving reaction rate. One of reasons that chemistry is so complex lies in the fact that it can be represented at the macroscopic level and the microscopic level. According to Hakimah et al. (2021:6), most students still have a misconception that the reaction rate would run slow if the mass of the substance is large, the concentration is also large, and the reaction temperature is low.

Ahiakwo and Isiguzo (2015:113) reported that students encounter difficulties in chemical kinetics, because they are unable to differentiate reaction rate and reaction time in understanding that the reactions had the highest rate at the beginning of the reaction and the lowest at the end. The nature of chemical reaction in chemical kinetics involving breaking and making of bonds and electron transfer is such that the students can hardly conceptualise it. Michaliskova and Prokša (2018:83) indicated that misunderstandings also arise because of students' misinterpretation of the terms of chemical kinetics and chemical equilibrium, and thus they cannot distinguish between how far (thermodynamics) and how fast (kinetics) a chemical reaction will take place. Karous,

Nihant and Leyh (2017:1) have shown that chemical kinetics is one of the many abstract concepts in chemistry that remain difficult for students, and explains that this can persist with senior students at university level. It can therefore be suggested that engaging students in modelling activities can improve their conceptual understanding of chemical kinetics.

Okumus et al. (2019:158) showed that various studies have been carried out to determine the effects of models on the understanding of chemical concepts. These studies revealed that the models had a positive effect on the learning process, as they provided students the opportunity to experience it first hand and allowed the students to visualise the events more accurately in their minds. Success in studying Chemistry requires students' sound reasoning skills, fundamental scientific knowledge, ability to work with scientific knowledge, and excellent problem solving skills (Ortiz, 2019:34). Accordingly, it has been reported that model studies conducted with cooperative learning offer students the opportunity to better associate macro-micro and symbolic dimensions. Therefore, knowing the misconceptions by students are important and should be pursued in further learning models to prevent and reduce them (Pikoli, 2020:2). Effective science learning often requires that students construct new representations that vary in important ways from ones used in everyday life. Science entails new ways of seeing data in terms of idealised representations or models. Science generally entails mathematical relations, physical intuitions, and sensorimotor action schemes in these models.

Siswaningsih and Widasmara (2019:3) have shown that most misconceptions experienced by students are at dynamic equilibrium concept with stated that at the equilibrium state, concentration of reactant and product are constant because at equilibrium state concentration of reactant and product are the same. Hanson (2020:77) conducted a survey with teacher trainees whom clearly indicated that their students in Grade 11 have challenges in understanding many basic chemistry concepts such as phase equilibria, solution equilibria, periodicity, hybridisation, stoichiometry, and especially chemical equilibrium. Almost all the students come to class with alternative conceptions, or misconceptions as they sometimes call them, and that they show more

alternative conceptions with the topic, principles of chemical equilibrium, and analytical chemistry. Koretsky (2020:106) has shown that there are several alternative conceptions in educators on key terms, which are used to explain the basic concepts of chemical equilibrium. Instead of key terms like system, open and closed system, shift, equilibrium, constant, and state of balance being applied after developing the concepts, these are applied as raw English words without scientific meaning, just as the textbooks used by both educators and learners fail to explain the key terms.

Basheer et al. (2018:3111) focused on conceptions of the conservation of mass during combustion among students in the Jewish sector. It was found that twice as many students gave correct answers regarding the conservation of mass during combustion in both open and closed systems after the subject had been taught than before. One possible reason for this is that students may find it difficult to distinguish the macroscopic from the microscopic world, and therefore, do not understand chemical reactions and the conservation of mass. Most students had the incorrect conception regarding computations involving mass and time (Ahiakwo & Isiguzo, 2015:124). Students can mention any factor that can accelerate the reaction rate. However, students cannot explain how these factors can accelerate reaction rate, this is in line with the results of interviews with teachers in the school who stated that students know what factors affect reaction rate, but students cannot explain how these factors accelerate reaction rate (Sari et al., 2019:3).

Learners should be taught that only a change in temperature can result in a change in the K_c value for a particular reaction (Siswaningsih & Widasmara, 2019:4). If the forward reaction is exothermic, a decrease in temperature will result in an increase in the K_c value. If the forward reaction is endothermic, an increase in temperature will result in an increase in the K_c value (DBE Diagnostic report. 2019:216). Siswaningsih and Widasmara (2019:4) have shown in his study that most learners have been struggling to deal with calculations involving the equilibrium constant (K_c) value, and also the equilibrium constant (K_c) based on gas pressure. The results showed that students hold a lot of misconceptions in the areas of approaching to equilibrium, characteristics of equilibrium, changing equilibrium conditions and adding catalysts, and that the reasons

for these misconceptions might be rooted in inadequate knowledge and everyday experience. Adeoye and Ajeyalemi (2018:9) indicated that students have learning difficulties in chemical kinetics and chemical equilibrium.

2.4.3 Teaching of reaction rate as atopic

Summer, Shafi and Naqvi (2014) showed that some of these misconceptions are known to come from teachers. Summer et al. (2014:4) further stated that teachers can minimise the difficulties in concept building by providing better perspective related to the basics of the subject. Rate of reaction as a highly structured topic is a central part of chemistry curriculum and is an abstract chemical topic, which is also important in learning other fundamental chemical concepts such as chemical equilibrium (Seçken & Seyhan, 2014:358). Ozdilek et al. (2018:945) indicated that science is one of the most difficult lessons in general to learn because of the abstract subjects and concepts it contains. Research has been conducted in the fields of physics and chemistry education in order to test effective science learning and to eliminate the misconceptions about the subjects. This research suggested that students have serious problems with the understanding of abstract concepts of science.

Vergis (2017:4) has shown that most of the students also had difficulties in understanding activation energy. For example, a number of students stated activation energy as the kinetic energy of the molecules, and that the catalyst would not affect or change the mechanisms of the reaction. Okumus et al. (2019:158) attributed the difficulty of learning physical science to a wide range of factors such as learners' prior knowledge, experiences, cognitive resources, and interests the learners bring into the classroom. Okumus et al. (2019:158) also confirmed that the difficulty of learning chemistry has been well documented and has been attributed to various factors such as the abstractness of the subject, the complex nature of the calculations involved, and the remoteness of the language used. If there is a correlation between teacher subject mastery and learners' achievement, we expect science educators to be conversant with the principles of chemical kinetics.

Karsli and Ayas (2014:664) detected prospective chemistry teachers' misconceptions. It is very likely that these misconceptions can be passed on to learners. It is a known fact that misconceptions resist change, and that when looking into the reasons for these misconceptions, some of them resulted from teachers. This means that teachers are potentially one of the sources producing alternative conceptions (Vergis, 2017:8). Phrased differently, if teachers or student teachers do not fully hold sophisticated subject matter knowledge and think their existing conceptions are correct, they may engender students' alternative conceptions. According to Vergis (2017:8), the objectives of chemistry education in schools cover the fundamental concepts of chemistry that learners should comprehend, and the chemical processes that lie behind every day phenomena. In this investigation focus is on factors such as concentration, temperature, surface area, and catalyst as they affect the rate of chemical reactions.

Koretsky (2020:108) indicated that research by educators can complement efforts of other stakeholders to improve the quality of teaching so that chemistry makes sense to the learners. The practicing educators should take active part in chemistry education research, so that the results can easily be implemented in their classes with a sense of ownership. There is no single method or approach which is the most appropriate to teach the above concepts of reaction rate, therefore educators should use different methods to achieve good results (Ahiakwo & Isiguzo, 2015:113). It becomes concerning when some chemical educators perceive chemical kinetics and related concepts difficult to teach. Studies have also reported that students perceive chemical kinetics and related concepts difficult to learn. Chemical educators have been advocating the use of Systematic Approach to Teaching and Learning (SATL) in preparing lesson presentations for chemical concepts including chemical kinetics (Ahiakwo & Isiguzo, 2015:114). In the SATL technique the concepts are positioned in such a way that the relations between a series of ideas and issues are made logical. The basic goal of this approach is the achievement of meaningful learning by the learners. In preparing lessons based on this approach and other techniques, reference is made to the previous experience or what the learner already knows. SATL model seems to suggest that one way of teaching a learner is to use what is in the learners' memory. A learner's construct of an idea or concept could be correct or incorrect. Being correct or incorrect

depends on the teacher's standard by way of matching the learners' response to a task with his/her marking instrument/ guideline.

Fahmi and Irhasyuarna (2017:54) have shown that misconceptions are embedded in students' alternative belief system that is not in accordance with generally accepted explanations and prove to be true of the phenomenon. Fahmi and Irhasyuarna (2017:54) identified the possible causes of students' misconceptions on reaction rate at school teaching, outside school teaching, everyday experiences, social environment, and intuition. What is concerning in the misconceptions are when someone knows a misconception, but he/she does not realise it was happening. It needs hard work to correct misconception and not only to reconstruct the understanding of learners (Fahmi & Irhasyuarna, 2017:54).

All these difficulties manifest themselves in all areas of chemistry and as such, an increasing number of studies have focused on learners' difficulties with the concept reaction rate. Sari et al. (2019:2) misconceptions result from the interaction between learners and environments. Misconceptions on reaction rate are passed onto the learners by some chemistry teachers who attended teacher education colleges and Universities where their misconceptions were not identified and clarified. Learners can experience misconceptions if their concepts are different from their teachers (Siswaningsih & Widasmara, 2019:1). Some teachers usually use learners' pre-existing knowledge as the starting point during teaching and learning, but fail to explain in detail that what learners give as responses to the posed questions are not accepted by the scientific community (Siswaningsih & Widasmara, 2019:1).

Pikoli (2020:4) have shown that teachers should teach the learners how to links these levels, and how to understand the interactions and distinctions between these levels. This is important in comprehending chemical concepts. It was also indicated that many studies have shown evidence of secondary and undergraduate students' alternative conceptions on the chemical kinetics unit of chemistry. According to Ortiz (2019:35), students may undergo instruction in a particular science topic, do reasonably well in a test, and yet, do not change their original ideas pertaining to the topic even if these

ideas are in conflict with the scientific knowledge they were taught. Hanson (2020:89) has shown that learners have difficulties visualising chemical phenomena at the sub-microscopic level, and that the learners find it difficult to relate macroscopic, sub-microscopic, and symbolic levels to each other.

Wardah et al. (2020:3) observed that learners defined reaction rate is the amount of substance turning into products per unit time at constant temperature and concentration, students overgeneralised that rate of reactions always decreases as the reaction proceeds without considering the order of the reaction and that catalyst increases reaction rate without changing mechanism (Karsli & Ayas, 2014:664). Some learners concluded that forward reaction rate + reverse reaction rate = ΔH , rate of a reaction is zero when it is at equilibrium and rate of a zero-order reaction increases with time if the “kinds” of products increase. Some misconceptions identified are that if the reactant of a zero-order reaction was in gas phase, it would be written in the rate equation; if a gaseous reaction is heated, the rate of the reaction will increase; however, if reactants which are in solid phase are heated, the reaction rate will remain constant during the reaction; rate constant (K) depends on temperature, concentration, and volume of the reactants; crumbled substances move and so react faster than a big piece of a substance, and particles in lower volume have greater speed than the ones in higher volume (Wardah et al., 2020:3).

Teachers play a great role in how students understand and learn the concepts taught in class. Studies show that teachers reflect their already-existing conceptual constructs and their problem-solving processes on students. This is also true of the misconceptions reflected in chemistry classes, especially when abstract concepts are being taught (Kolomuç & Tekin, 2015:84). Teachers’ lack of content knowledge causes the unawareness of students’ misconceptions, alternative conceptions, and learning difficulties, Students’ conceptions, which are different from those generally accepted by the scientific community, have been called misconceptions, preconceptions, alternative frameworks, or alternative conceptions (Bozkoyun, 2014:85). The role of both the didactics and the teachers themselves should therefore be to identify these difficulties, preconceptions, and misconceptions that have built students’ knowledge structures, and

also to find ways to eliminate and prevent them in order to make the learning process in schools better and more effective (Michaliskova & Prokša, 2018:82).

According to Kolomuç and Tekin (2015:84), chemistry is the science of matter and the changes it undergoes. It also attempts to explain chemical phenomena of everyday life. The objectives of chemistry education in schools cover the fundamental concepts of chemistry that students should comprehend, and the chemical processes that lie behind everyday situations. It is suggested that school education should enable students to understand their lives. The unit on “Chemical Reaction Rate” covers many fundamental chemistry concepts. The topics in the unit are the rate of reaction, activation energy, and factors affecting the rate of reaction, collision theory, catalysts, enthalpy, and reaction mechanism (Okumus et al., 2019:156). These concepts are of utmost importance in order to understand the relations between chemical change and energy, the types of chemical reactions, and the chemical change processes. According to Taştan and Boz (2014:151), teachers can guide learning of learners having different backgrounds by creating an environment in which they are actively involved in their learning.

According to Kirik and Boz (2012:221), science teaching has been the central issue of many research studies for many years. The principal goal of science teaching is to make learners capable of understanding the nature of the world by enabling them to gain knowledge. Students’ idea of ‘reactions as rearrangement of particles’ can be tenacious. Some students could apply it even to dissolution of ionic solids. Appropriate teaching strategies should be adopted so that such a view can be developed into the atomic model of reactions (Cheng & Gilbert, 2017:18). It is through effective teaching practices, where learners are engaged actively in the learning process, which promotes the achievement of intended objectives of producing scientific literate citizens with minimum misconceptions of chemistry concepts especially on rate of chemical reaction (Koretsky, 2020:109).

Turanyi and Toth (2014:110), in their research project, attempted to ascertain what conceptions learners held about chemical reaction rate before the teaching sequence.

They identified misconceptions before and, during the teaching sequence, analysed how peer group responses enhance understanding, and also evaluated the teaching schemes. Ahiakwo and Isiguzo (2015:113) found that learners' understanding of chemical reaction rate often relied on previous conceptions, but their performance improved after they are exposed to a wide range of relevant examples. He further noted that learners have a number of misconceptions and confusions on the addition or increase of one of the factors after the reaction has taken place. According to Ahiakwo and Isiguzo (2015:111), practical work without feedback did very little to enhance and stimulate learners' ideas about chemical reaction rates. This means that teachers have to take into consideration the amount of time, learners' prior knowledge, and use of familiar examples when teaching this topic.

Cheng and Gilbert (2017:97) indicated that chemical reaction rate is interwoven and connected with other chemistry topics, and as such it plays a very vital role in the study of chemistry from elementary level up to university level. Reaction rate lessons taught in class are usually a mixture of the teachers' own views and the textbook quotations, because most high school science teachers depend on the textbooks when giving instruction and some textbooks can be misleading, as they are poorly written or edited. According to Wardah et al. (2020:2), learners' misunderstanding of correct conceptions of chemical reaction rate generally originated from the learners experiences in their everyday lives. Teachers should always be aware of the learners' prior knowledge and misconceptions on reaction rate because they serve as strong indicators of learners' achievement (Turanyi & Toth, 2014:110).

Teachers can guide the learning of students with different backgrounds by creating an environment where they are actively involved in their learning (Kırık & Boz, 2012:2). Cooperative learning, which is based on constructivism, is a suitable strategy to deal with the misconceptions and improve learners' conceptual understanding of abstract concepts. According to Bryan, Glynn and Kittleson (2011:1049), research studies indicated that positive motivational beliefs such as perceptions of high self-efficacy, a focus on the mastery of goal, high value and interest in task, and low levels of test anxiety, are positively related to higher academic achievement. The major goal of

teaching science is to make learners understand the nature of the world by gaining knowledge. Contemporary teachers have to modify their teaching methods because teaching of higher level reasoning and critical thinking does not depend on what is taught but rather on how it is taught (Kırık & Boz, 2012:221).

According to Ortiz (2019:35), students may undergo instruction in a particular science topic, do reasonably well in a test, and yet, do not change their original ideas pertaining to the topic even if these ideas are in conflict with the scientific knowledge they were taught. Success in studying Chemistry requires students' sound reasoning skills, fundamental scientific knowledge, ability to work with scientific knowledge and excellent problem solving skills (Ortiz, 2019:34). According to Duit and Treagust (2014:483), students may undergo instruction in a particular science topic, do reasonably well in a test, and yet, do not change their original ideas pertaining to the topic even if these ideas are in conflict with the scientific knowledge they were taught. Learners demonstrate conceptual understanding when they provide evidence that they can recognise, label, and generate examples of concepts.

Chemistry is a field of science that emphasises the mastery of concepts. In the learning process, concepts are things that need to be understood, studied, and mastered by students. Chemical concepts form within students gradually through their experiences and interactions with the natural surroundings. Learners understand what factors influence reaction rate but students do not understand how these factors can accelerate reaction rate (Sari et al., 2019:1). Alternative conceptions of the students will be reconstructed during the learning activities. The results of the reconstruction process of the student studying chemistry among others, is the understanding of scientific concepts (Pikoli, 2020:2). To overcome students' misconceptions, a large amount of research has explored the effects of several instructional tools based on conceptual change approaches in science, such as concept maps and conceptual change texts. This type of instruction was designed to address students' misconceptions about rate of reaction concepts and to eliminate them by considering four conditions for conceptual change (Evagorou et al., 2015:220).

According to Ozdilek et al. (2018:945) students had difficulty in relating rate and equilibrium. They think that if a system at equilibrium is disturbed by some change, the system will shift so as to partially counter act the effect of change and the rate of the reaction to which the equilibrium shifts will be greater when a new equilibrium is established. It is clear that students use pre-existing conceptions constructed from reflection on previous experiences to reason about newly presented science concepts, and to make sense of their instructional science experiences (Fahmi & Irhasyuarna, 2017:83). While students often predict correctly that reaction rates for a simple ideal gas reaction will become faster at higher temperatures, they also often mistakenly think that the reaction equilibrium will shift towards the products at higher temperatures as well (Okumus et al., 2019:155).

Evidence of students experiencing misconceptions is that when students choose the correct answer but give the wrong reasons. This indicates there is a problem in the self-learners when they construct knowledge they acquire (Fahmi & Irhasyuarna, 2017:56). Misconceptions that are found on these items are that "the reaction rate may not be deductible and definition of reaction rate is the number of reactions that take place per unit time" (Karsli & Ayas, 2014:665). Because the definition of the rate that is often written in the book is a change in the concentration of reactants or products per unit of time or changes in unit time, and also the words "rate is a measure of how fast or slow a reaction to take place" or "rate tells you how fast or how slow a process is happening (Kırık & Boz, 2012:2). The errors of construction are caused by intuitive thinking and humanistic thoughts.

Research conducted by Fahmi and Irhasyuarna (2017:55) indicate they have found that the students understanding will form better if the students are told what is associated with a concept so that they can sense of what is learned. According to Kolomuç and Tekin (2018:8), during this time, most students consider the definition of a thing is not too important, but if you lose the core of a definition of the word, learners will be confusion as to develop its concept. This is also consistent with the results of research. Many learners who think the reaction rate is based on the time because students are more familiar with the measurement of time than measuring changes in a concentration

or amount of a substance (Kaya & Geban, 2012:37), and ultimately concluded that the reaction rate is based on the number of reactions that occur within a given time because learners are not guided to find out how to measure the reaction rate.

Chemistry tends to be a very abstract science and therefore many students entering the course find it challenging and often difficult to master. Additionally, children attempt to make sense of the world around them very early on in their lives (Fahmi & Irhasyuarna, 2017:55). To them, this learning is their "truth" whether or not the interpretation is valid or not. From their early years they continue to build on these conceptions they have gathered and any synthesising of new material continues and is highly influenced by their prior beliefs and learnings (Taştan & Boz, 2014:167). The danger lies in those preconceptions that are inaccurate (also known as misconceptions or alternate conceptions) especially if the student is so convinced and hangs on to the belief or learning (Fahmi & Irhasyuarna, 2017:55). Most these explanations are correct because it make sense in terms of their understanding of the behaviour of the world around them. As educators are self-directed and know what they want to learn they have to be consulted.

The efficacy of the reform efforts rests largely on the educators; their voices need to be included in the design and implementation of inquiry based curriculum. According to Koretsky (2020:111), the novice educators has nowhere to refer to therefore we need to tap into the knowledge of subject experts for the benefit of the novice educators. We need research that can be used in teacher training to inform teachers of the 'how' and 'why' of conceptual development, so that practising teachers have an integrated framework for understanding learning and curriculum that enables them to plan and teach as constructivists (Ortiz, 2019:33). Students face problems in understanding the subject despite its association with daily life's experiences. Students' difficulty in understanding the subject is to some extent contributed by the abstract nature of the concepts involved in the subject. The students need not to understand only the symbols, terminologies, and theories used in learning Chemistry concepts (Ortiz, 2019:33). At equilibrium, the rates of the forward and reverse reactions are equal, resulting in the dynamic "no overall change" position. Although this appears quite

straight-forward, the literature reveals several ways in which students confuse rate of reaction with chemical equilibrium ideas.

Calik, Kolomuç and Karagölge (2014:433), in a post-teaching study with thirty 17-year old chemists, revealed that about 25% thought the rate of the forward reaction would increase from the time reactants were mixed until equilibrium was established. This may reflect the perception of the forward and reverse reactions being separate events. Kirik and Boz (2012:9) found some students who consider concentrations of reactants and products are equal at equilibrium. These students may be directly confusing equality of rate with concentration. They have reported that about 50% of students think that changing conditions results in an increase in the rate of the favoured reaction and a decrease in the rate of the other reaction. They have found similar reasoning among 35% of undergraduate chemists and 49% of chemistry teachers. Some students (27%) extended this to the role of catalysts, suggesting that the rates of forward and reverse reactions would be affected differently (Turanyi & Toth, 2014:113). They reported (without figures) that both undergraduate chemists and high school teachers tend to associate a high K_c value with a very fast reaction.

Chemistry has been described as a difficult subject by students of different ages in different countries, as it has a lot of abstract concepts (Karsli & Ayas, 2014:667). They determined that “reaction rate” was one of the difficult topics to teach and understand for teachers, student teachers, and students because of it being both complex and contain qualitative and quantitative variables. According to Ahiakwo and Isiguzo (2015:117), the impact of teaching is evidenced in the performance of the learners. It is therefore suspected that there could be a link between a growth in a science education project and the performance of science students. Kaya and Geban (2012:39) observed the lesson presentation by a teacher in one of the public high schools in Turkey, and found that the teacher mostly used lecturing methods during instruction. The teacher should enhance and encourage discussion in the environment for the students. The teacher also solved numerical problems to make practice about the concepts. The teacher taught the subjects without considering students’ misconceptions and previous knowledge. The students were mainly passive during the instruction.

Research findings have shown that a huge gap existed between the intended chemistry curriculum and actual happenings when students learn chemistry. Students' inability to demonstrate good understanding of very basic concepts of the subject has been reported. Adeoye and Ajeyalemi (2018:17) determined high school students' and undergraduates' ideas related to reaction rate and its relationship with concentration or pressure. Their results suggested that school students tended to use macroscopic modelling rather than particulate and/or mathematical modelling; undergraduates were more likely to give explanations based on theoretical models (Karsli & Ayas, 2014:667). Students at both levels had conceptual difficulties in making the transformation within and across different theoretical models, indicating that they were not able to use scientifically acceptable concepts of reaction rate across context, and displayed misconceptions. According to Ahiakwo and Isiguzo (2015:118), chemical kinetics, one of the most fundamental concepts in chemistry, is regularly taught in both school and university courses.

It is necessary to identify and remediate students' misconceptions in chemical concepts through appropriate instructional strategies. Obviously, ordinary form of instruction such as lectures, laboratory activities, discovery learning, or simply reading textbooks are not very successful at overcoming students' misconceptions in some chemistry topics (Ahiakwo & Isiguzo, 2015:117). Some of the identified reasons for students' misconceptions include lack of deep conceptual knowledge, inability to integrate ideas to coherent conceptual framework, inability to represent the macroscopic to microscopic and symbolic concepts, inadequate basic mathematical knowledge, and inadequate methods of the teaching (Adeoye & Ajeyalemi, 2018:7). Several instructional strategies have proven to be effective in achieving conceptual change and assist to learn correct concepts in science. Kaya and Geban (2012:41) suggested computer animation for nature of matter and transformation, and conceptual change oriented instruction through demonstrations for rate of reaction.

According to Adeoye and Ajeyalemi (2018:7), thermodynamics concepts such as heat, temperature, and equilibrium are widely studied both at elementary and secondary levels and students' alternative concepts are well documented. Graduates who have a

BSc in chemistry could enrol in the one and half year (three semesters) master without thesis programme, if they want to be chemistry teachers in secondary schools. Turanyi and Toth (2014:113) suggested that these misconceptions articulated how these prospective teachers differentiate the concepts of chemical thermodynamics and kinetics, but did not provide an in-depth explanation of their personal views. To address this limitation, thirteen prospective teachers were interviewed to clarify their written responses and to further probe conceptual understandings of the questions asked in the test. Interviewees were selected on the basis of their responses on the written test. Teachers should carefully and thoroughly give information (academic or non-academic), not to be ambiguous, incomplete, and allow for misunderstandings. Therefore, it is important for teachers to understand the misconceptions first (Duit & Treagust, 2014:483).

An understanding of the misconceptions can be constructed by reading some of the relevant literature; to avoid the language barrier, it is important to know the other terms of the misconceptions. Turanyi and Toth (2014:113) mentioned some of the terms used in the literature that is equivalent to misconceptions, such as alternative conceptions, alternative frameworks, and spontaneous knowledge. Fahmi and Irhasyuarna (2017:84) posit that they have found that student teachers' success in higher order thinking skills was less than 50%. These results showed that teacher education programmes in Science education need to put more emphasis on teaching activities to improve teachers and student teachers' higher order thinking skills. According to high school teachers, high school curricula focus more on covering content than on developing understanding in learners. According to Kirik and Boz (2012:9), if teachers set up a problem involving moles, students get the answer but they do not understand what the teacher is doing when translating a chemical equation into a mathematical statement, because teachers introduce concepts and subjects that are tied together in the learners' mind, but fail to promote information about how they are connected with each other.

There is an important connection between what teachers think and what they do. Bozkoyun (2014:31) stated that there is a reciprocal relationship between teachers' thought and teachers' action. Teachers are regarded as the authoritative experts, the

main sources of knowledge, and the focal point of all activities in our country. According to a study by Taylor and Kowalski (2015:63), the students are the recipient of information already acquired by the teacher but most of the educators agreed that knowledge is not transmitted from one person to another; it is constructed by each learner as a result of interactions with reality and negotiations of meaning with other people. According to Taştan and Boz (2014:163), inappropriate teaching strategies and learning activities provided by teachers can cause misconceptions in Science or what some researchers referred to as children's science. The major reasons for the difficulties at the junior level are the fact that learners sometimes are insufficiently equipped with the necessary science concepts.

Misconceptions will always exist and will never be completely avoidable. Since they are something that cannot fully be prevented (they are natural), teachers must be prepared to receive these misconceptions in the right way. Teachers must know how to receive these misconceptions that students possess as they enter their classrooms (Koretsky, 2020:107). In fact, because alternative conceptions are not necessarily spontaneous ideas, they may result from instruction, or teachers, or the textbooks or the discrepancy between daily language and scientific language or students' social environments (Karsli & Ayas, 2014:664). This means that teachers are potentially one of the sources producing alternative conceptions (Kaya & Geban, 2012:33). Phrased differently, if teachers or student teachers do not fully hold sophisticated subject matter knowledge, and think their existing conceptions are correct, they may engender students' alternative conceptions. For this reason, remedying student teachers' alternative conceptions would be worthwhile to prevent teacher-based alternative conceptions.

Teachers play a great role in how students understand and learn the concepts taught in class. Studies show that teachers reflect their already-existing conceptual constructs and their problem-solving processes on students (Kolomuç & Tekin, 2015:84). This is also true of the misconceptions reflected in chemistry classes, especially when abstract concepts are being taught. Problem-solving processes and explanations teachers use set an example of learning and presenting knowledge for students. In the learning process, students can construct knowledge correctly when they receive assistance from

teachers (Kolomuç & Tekin, 2015:85). These may lead to misconceptions as chemistry classes include such processes as problem solving, explaining, or relating concepts. There is a need to review how we teach the basic ideas which comprise our subject, to help students develop the “molecular spectacles” required for further progress (Ozdilek et al., 2018:945). Among the points made is a need to establish an understanding of how teachers teach, in order to share what “works”, and to develop improvements in our practice.

Teaching programs are looked at to classify and point out the sequence of suggestions that would help in understanding chemical equilibrium and application of the LCP. According to Evagorou et al. (2015:4), researchers have pointed out methods of instruction that teach students to build an understanding of chemical equilibrium laws of chemistry that improves their problem and their understanding of concepts. Some literature proposed that misconceptions will constitute very different problems for learning depending on the ontological status that the learner ascribes to a certain concept (Kariper, 2014:16). Karsli and Ayas (2014:664) presented empirical evidence that students successfully utilise prior conceptions to learn more advanced knowledge, and questioned to what extent misconceptions interfere with learning expert concepts. It is critical to provide students with opportunity to verbalise their ideas to promote concept building and remediate misconceptions. Teachers can be referred to as a catalyst that brings about changes in the behaviour of the learners, and play a central role in the actualisation of educational goals and the survival of the educational system.

The deep-seated misunderstandings should be identified, diagnosed, and addressed. Kariper (2014:16) investigated to determine the nature and extent of student misconceptions in chemical equilibrium, and to ascertain the degree to which certain misconceptions were related to chemistry achievement, and to performance on specific tasks involving cognitive transformations characteristic of the concrete and formal operational stages of thought. According to Manitoba Education Foundation (2014:2), students learn most effectively when their study of science is rooted in concrete learning experiences related to a particular context or situation, and applied to their world of experiences, where appropriate. Ideas and understandings that students develop

should be progressively extended and reconstructed as students grow in their experiences and in their ability to conceptualise more deeply. Learning involves the process of linking newly constructed understandings with prior knowledge, and then adding new contexts and experiences to current understandings. According to Ejidike and Oyelana (2015:606), a greater deal of work has been done in an effort to identify problem that are inherent in the teaching of chemistry in secondary schools. These factors influence the effective teaching of chemistry which in turn plays a vital role in the lives of the students as it affects their performance.

2.4.4 Training for science teachers

During the last decade research and reform documents have been calling for a total change in science curriculum and scientific processes (Evagorou et al., 2015:4). Scientific practices, part of scientific processes are cognitive and discursive activities that targeted in science education to develop epistemological understanding of appreciation of science. This is because most teachers have grasped misconceptions at an early age, went through both secondary and tertiary education with them without been detected and rectified. Taştan and Boz (2014:153) detected prospective chemistry teachers' misconceptions. It is very likely that these misconceptions can be passed onto learners. They also said that it is a known fact that misconceptions resist to change and that when looking into the reasons for these misconceptions, some of them are known to have resulted from teachers. According to Kolomuç and Tekin (2015:84), the objectives of the chemistry education in schools cover the fundamental concepts of chemistry that learners should comprehend and the chemical processes that lie behind every day phenomena. In this investigation focus will be put on factors such as concentration, temperature, surface area, and catalyst as they affect the rate of chemical reactions.

Kolomuc and Karagolge (2014:432) posit that in literature, there have also been many studies concerning chemical reaction rate. There are two main ideas dominated with those studies namely, to find the alternative conceptions and to overcome the identified alternative conceptions. Misconceptions are words or terms which are parallel to the

scientific conceptions normally used by the science community. These conceptions are also referred to as preconceptions, alternative frameworks, or alternative conceptions. Bidi (2016:22) has indicated that misconceptions are created by different sources, thus, they may arise from textbooks, may arise from prior to formal instruction or as a result of interactions with teachers, physical and social world. Kolomuc and Karagolge (2014:432) have shown that even students who are been well trained and exhibit all the overt signs of success, faithful attendance at good schools, with high Grades and test scores, typically do not display as adequate understanding of material and concepts with which they have been working.

In fact, because alternative conceptions are not necessarily spontaneous ideas, they may result from instruction, or teachers, or the textbooks or the discrepancy between daily language and scientific language or students' social environments (Karsli & Ayas, 2015:668). This means that teachers are potentially one of resources producing alternative conceptions. The conceptual change approach requires teachers to have in depth subject content knowledge and assessment techniques (Vergis, 2017:4). Phrased differently, if teachers or student teachers do not fully hold sophisticated subject matter knowledge and think their existing conceptions are correct, they may engender students' alternative conceptions. For this reason, remedying student teachers' alternative conceptions would be worthwhile to prevent teacher-based alternative conceptions (Ahiakwo & Isiguzo, 2015: 113).

It becomes worrisome when some chemical educators perceive chemical kinetics and related concepts difficult to teach (Vergis, 2017:4). Studies have also reported that students perceive chemical kinetics and related concepts difficult to learn. Research has revealed that not only secondary school but also pre service science and chemistry teachers, and science and chemistry teachers have various misconceptions about the reaction rate (Okumus et al., 2019:156). So there is really a need for University or college curriculum to be structured in such a manner that will reduce and eliminate the misconceptions. The fact that teachers have misconceptions reveals the importance of in-service training given to teachers because these teachers mislead students, as well. Another important issue is that pre service teachers have misconceptions. It is important

to eliminate and reduce these misconceptions in their undergraduate education with the aim of preventing pre service teachers from misinforming their students when they start to practice their professions (Vergis, 2017:4).

According to Hanson (2010:72), research results have shown that several of the more common misconceptions are retained, even at higher educational levels among university students, and sometimes beyond that. This means that irrespective of the type of training one underwent, misconceptions can still prevail after university education. Chemistry course has been described as a difficult subject by students of different ages in different countries it has a lot of abstract concepts (Karsli & Ayas, 2014:668). It was determined that “reaction rate” was the one of the difficult topics to teach and understand for teachers, student teachers and students because of being it both complex and contain qualitative and quantitative variables. In particular being the questions relating to reaction rate in many chemistry textbooks mathematical, providing conceptual dimension very little space and coming alternative concepts in the learning environment of students, these prevents conceptual understanding. There are studies conducted to determine alternative conceptions about reaction rate concepts in the literature (Karsli & Ayas, 2014:668).

Misconceptions can be avoided hopefully with effective teaching practices for content structured lessons (Karsli & Ayas, 2014:667). Based on captured material effective learning can be realised through: giving a brief overview prerequisite knowledge and interest; submit an explanation in a step-by-step, clear, and detailed; provide active practicum and ask questions; guiding learners practice; provide systematic feedback and corrective instruction; provide explicit instruction and monitor the work of learners. Other studies have also shown that laboratory methods can develop a deeper understanding for the students on the material reaction rate than traditional learning (Fahmi & Irhasyuarna, 2017:56). In cases where teachers demonstrate content knowledge gap, intensive workshops should be organised to ensure that teachers are re-skilled and re-trained (Vergis, 2017:62).

Many faculty members and teaching assistants teaching first-year undergraduates reported that students in introductory science courses have little prior knowledge of the field or topics covered. To make matters worse, what these freshmen do know “is poorly organised, incomplete or simply inaccurate (Vergis, 2017:62). Kolomuç and Tekin (2015:1) examined learners’ errors while solving numerical-chemical equilibrium problems in an elective course and they found that many learners have expressed that rate of reaction means the same as extent of reaction. They have also realised that learners applied LCP to rate of reaction concept. Calik et al. (2014:433) have examined undergraduate students’ conceptual understanding of chemical kinetics. Their study has indicated that though most of the students knew the factors affecting reaction rate, most of them disagreed that pressure and volume are also factors affecting reaction rate in gaseous phase.

A continuous teacher training is the keystone of improvement and transformation in schools, for personal growth and professional development (Ejidike & Oyelana, 2015:607). In-service training can be in the form of on-the-job training, workshops, post qualification courses, formal or informal, structured or unstructured. Furthermore, on the part of government, cutting backs in funding and unfulfilled promise are the problems, where government promise some allowances for the science teachers and raise their morale; surprisingly these promises are not fulfilled (Vergis, 2017:8). So lack of encouragement to teachers by the government also contributes to ineffective teaching of chemistry. According to Hanson (2020:71), a student’s misconception could hinder comprehension of subsequent related concepts and obstruct further learning. This supposes the urgency for improving the comprehension of teachers’ knowledge of students’ conceptions and difficulties in the learning process. Research results have shown that several of the more common misconceptions are retained, even at higher educational levels among university students, and sometimes beyond that.

Teaching in itself has common problems and challenges. Koretsky (2020:105) identified training as an area that contributes towards problems in teaching chemistry. He has further showed that educators who have not received in-service training for many years, as their initial training contributed to teaching that is inefficient and it is sensitive to the

needs and characteristics of growing children and ignorant of the ways in which they learn. Karsli and Ayas (2014:668) indicated that alternative conceptions are not necessarily spontaneous ideas; they may result from teachers, or the textbooks or the discrepancy between daily language and scientific language or students' social environments. This means that teachers are potentially one of the sources producing alternative conceptions (Karsli & Ayas, 2014:668). Phrased differently, if teachers or student teachers do not fully hold sophisticated subject matter knowledge and think their existing conceptions are correct, they may engender students' alternative conceptions. Also lack of suitable teaching materials and classroom accommodation reduces the effectiveness of a good deal of the teaching that goes on in school.

Marumure (2014:14) has identified the following as some of the problems faced in the teaching of science that Insufficient confidence and mastery by many educators of both subject content and basic teaching skills (like questioning) and language problems for both educators and learners, English being their second or third language. According to Marumure (2014:14), the disjuncture between school science is often Western-based curricula and textbooks (if available), African life outside the school environment, tension between African culture (for example values about the relation between adults and children) and the spirit of inquiry and critical questioning required in school science, such as poor material facilities (equipment) in schools and classrooms, and weak alignment of 'innovative' curricular aims and typical assessment and examination practices (Marumure, 2014:14).

2.4.5 Conceptual change

A teaching strategy to improve learners' understanding of Chemical Change in Physical Sciences or a learning process in which learners' alternative conceptions are reconstructed into the intended scientific conceptions (Bidi., 2016:17). Misconceptions are persistent and they cannot just be eradicated by mere instructions by the teacher. They need teachers to prepare more fascinating lessons that will force or entice learners to learn more. According to Hanson (2020:71), the inability of students to make useful interconnections among representational levels of nature and the wrong use of

language to explain chemical phenomena, especially with chemical equilibrium, lead to the formation of persistent alternative conceptions. Thus, it is important to tackle these problems and ensure that teacher trainees thoroughly understand the basic concepts on equilibrium, so that they can teach them from first principle, rather than from an algorithmic approach (Hanson, 2020:71).

A student's misconception could hinder comprehension of subsequent related concepts and obstruct further learning (Hanson, 2020:71). This supposes the urgency for improving the comprehension of teachers' knowledge of students' conceptions and difficulties in the learning process. Conceptual change is a slow process where a learner actively charges new information with their existing mental models (Kırık & Boz, 2012:222). Learners initially form a framework that is based on their daily experiences and when they come across new information, they actively start to restructure those initial mental models, and they may form synthetic models which is the synthesis of scientific knowledge. Such restructuring, in the strongest sense, involves changes in the core concepts of the theory, and the interrelation of these concepts. Because of the strong restructuring that occurs, it may not be possible to directly translate the core concepts in the new theory into those of the old theory (Vergis, 2017:43). At first learners have to be dissatisfied with their existing ideas, and the new knowledge to be presented has to be intelligible, plausible, and fruitful.

The conceptual change approach needs teachers to possess in-depth subject content knowledge and assessment techniques (Vergis, 2017:62). This conceptual change theory is relevant in this study, as it seeks to determine the prior knowledge of the learners, expose them to the expected content in terms of questions, and identify the content gaps on learners. But in order to achieve conceptual change, learners' enthusiasm, and interest in chemistry must be stimulated by posing fascinating questions to them; learners should be encouraged to make mistakes and express their thoughts during teaching and learning processes (Vergis, 2017:62). In addition, the learners' attitudes towards the subject must also be redirected by exposing them to the different career choices that are on the market and modelling the subject content. Teachers should have well planned lessons that are presented to the learners in a more

conducive environment so that learners could easily observe that their conceptions are different from those used in the presentation of the lesson. Teachers should also take their time in emphasising the key concepts in the lesson to enable learners to replace their conceptions that are inconsistent with the scientifically accepted concepts (Vergis, 2017:62).

Vergis (2017:36) suggested the following notion of Concept of Evidence by using examples encountered by first year undergraduate students taking science or chemistry courses. This model was used to identify and address the students' misconceptions before formal instructions take place to redirect the learners' thinking for conceptual change.

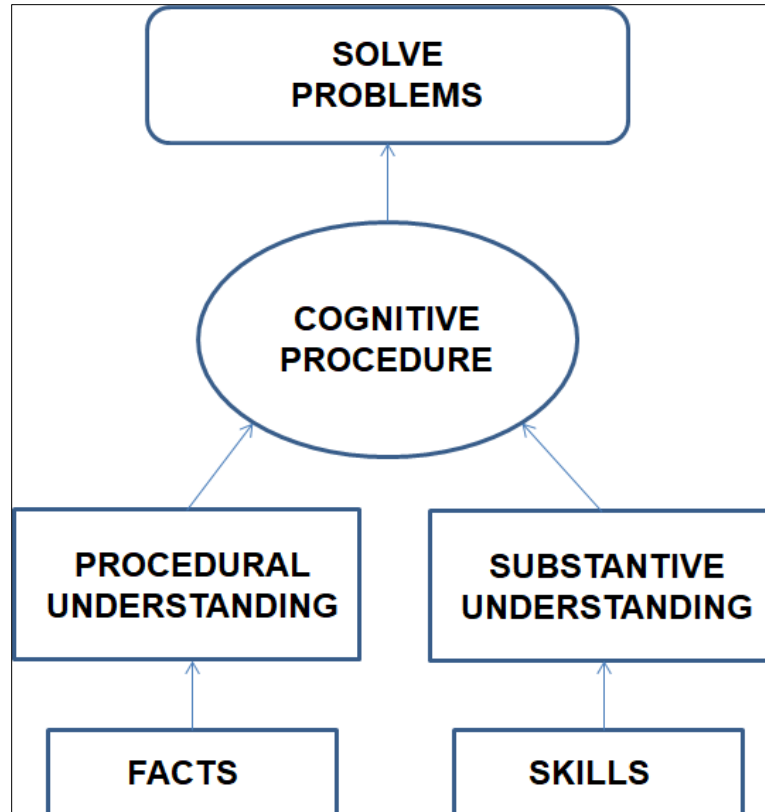


Figure 2.1: Concept of Evidence

2.4.6 Science as a social practice

Science is a difficult course for students since it is comprehensible and the phenomena, situations, or concepts in abstract and micro level are involved in all of the branches of

chemistry (Okumus et al., 2019:155). Chemistry, which is one of the branches of science, is said to be more abstract than other fields because it focuses on atoms, molecules, and compounds. This situation can make it difficult for the learners to understand chemistry, and cause the learners to have a negative attitude towards learning chemistry. According to Seçken and Seyhan (2014:138), chemistry concepts are abstract and difficult for students to understand correctly. In this regard, using techniques that enable the concretisation and visualisation of abstract situations, together with active learning methods, will be effective. Chemistry is classified as a difficult subject and that one of the characteristics of chemistry is abstract, sequential, and tiered (Sari et al., 2019:1). This means that understanding more complex chemical concepts requires a correct understanding of the underlying concepts. If students have difficulty on one of the basic concepts, then there is the possibility of students having difficulty with more complex problems.

When it comes to understanding this new and relatively demanding issue, learners can be confronted by various difficulties (Kırık & Boz, 2012:137). Learners may have various preconceptions, misunderstandings, and misconceptions that are not in accordance with scientifically accepted knowledge and negatively affect the next steps in the learning process. Science is something which is done (Vergis, 2017:65). It involves some kind of activity on the part of the scientist. As a result of this activity, knowledge is created. The role of the teacher of science is to tell a story about how that knowledge was created. The practicing educators should take active part in chemistry education research so that the results can easily be implemented in their classes with a sense of ownership (Marumure, 2014:2). There is no need for educators to re-invent the wheel.

Chemistry is a world filled with predominant events, interesting experimental activities, and flourishing knowledge for understanding the natural and man-made worlds. However, students face problems in understanding the subject despite its association with daily life's experiences (Ortiz, 2019:33). According to Michaliskova and Prokša (2018:83), one of the potential reasons for misconceptions and misunderstandings among upper secondary school students is that these misconceptions arose during the learning process of the issue at lower secondary school students. They then form the

wrong foundation for the learning process at the next level of education. Learning is a social event and learners should be provided with learning environments to work with their peers that can also allow for their individual differences (Kolomuç & Tekin, 2015:222). It is believed that social cultural factors such as collaboration and discussions are found to influence conceptual change since discussions may make learners aware of the need to change their concepts.

2.4.7 Adapted learning theories

The primary role of teachers in schools is to arbitrate learning. Knowledge cannot just be given to the learners; it is their responsibility to construct it from both their mental and physical experiences within the environment (Bidi, 2016:40). Knowledge is attained within a learner's mind through interaction with the environment. Learning is a physical and psychological activity and for it to be meaningful, one has to understand and integrate knowledge into one's cognitive structure. According to Turanyi and Toth (2014:117), learning must not only be meaningful to learners but should be based on different theories. The most important learning theories, according to Bidi (2016:40), are classical conditioning, operant conditioning, social learning, and cognitive learning. These four learning theories will be discussed briefly.

2.4.7.1 Classical conditioning

Classical conditioning is also known as Pavlovian or respondent conditioning, and refers to a learning procedure in which a biologically potent stimulus is paired with a previously neutral stimulus, or a basic form of learning in which one stimulus comes to serve as a signal for the occurrence of a second stimulus (Bidi, 2016:40). Learners acquire information about the relations between various stimuli. Classical conditioning plays a role in the learner's emotion and attitude, which are crucial catalysts for learning. Emotional learning can interfere with academic learning if the learner has a negative attitude to a teacher, the subject, school, or even peers at the school. The opposite is also true where a favourable environment enhances a learner's academic performance (Champion, 2013:121). According to Skinner (2019: 17), classical conditioning explains

how human beings acquire phobias. After an association has formed, the stimulus causes a response of fear and consequently humans develop phobias.

2.4.7.2 Operant conditioning

According to Champion (2013:41), operant conditioning theory is based on rewards that outline and preserve the behaviour of learners, or is a form of learning in which behaviour is sustained or changed through consequences. It is a type of associative learning process through which the strength of behaviour is modified by reinforcement or punishment. It is also a procedure that is used to bring about such learning. Miltenberger and Crosland (2014:37) described the role of operant conditioning as it applies to parenting. It describes the variables that may influence parent and child behaviour. Parents promote learning and abate problems by creating positive learning environments, and by effectively managing contingencies on the child's behaviour. According to Skinner (2019:15), operant conditioning is a method of learning that occurs through reward and punishment for behaviour. Through operant conditioning, an individual makes an association between a particular behaviour and a consequence.

2.4.7.3 Social learning

Social learning is an approach to personality that emphasises the interaction between personal traits and environment and their mediation by cognitive processes (Skinner, 2019:16). It is a theory of learning process and social behaviour, which proposes that new behaviours can be acquired by observing and imitating others. Learning is a cognitive process that takes place in a social context. According to Bidi (2016:40), social learning theory can be used to understand learner violence and destruction. The learners learn violence and destruction from their role models. The learners think it is acceptable social behaviour for the peer group if the act goes unpunished. It is important to note that peer group is the one that in most cases causes social pressure. Social learning theory provides the foundation for behaviour modelling. In behaviour modelling, an individual can learn new behaviours by observing. According to Miltenberger and Crosland (2014:39), the correct behaviour is demonstrated for the learner; the learner observes the model and then imitates the behaviour of the model.

2.4.7.4 Cognitive learning theory

Cognitive learning theory is used to understand how learners solve problems using the stored information as well as how learners retain information learned (Champion, 2013:42). According to Bidi (2016:41), cognitive science is an umbrella term for interdisciplinary innovativeness concerned with information acquisition and processing. Cognitive science includes research into language, learning, perception, thinking, problem solving, and knowledge representation. The cognitive view of learning deals with the way in which knowledge is gained through information acquisition, and how useful information is stored in the brain. Cognitive learning is based upon the idea that learning is a function of change in overt behaviour. Changes in behaviour are the result of an individual's response to events that occur in the environment (Skinner, 2019:16). Reinforcement is the key element in this theory.

2.4.8 Adapted learning strategies

2.4.8.1 Cooperative learning

Cooperative learning is a suitable strategy to deal with the misconceptions and improve learners' conceptual understanding of abstract concepts. According to Kirik and Boz (2012:2), cooperative learning requires learners to work together in small groups to support each other's learning and understanding and accomplish the shared goals. For social skills to be established, learners need to be taught how to communicate efficiently with each other, to know how to express their ideas, acknowledge others, deal with discrepancies, and manage conflict. When learners work in cooperative groups, their different perceptions, information, opinions, and conclusions will cause intellectual disagreements and cognitive conflict, which lead to conceptual change (Kırık & Boz, 2012:224). According to Bozkoyun (2014:12), cognitive conflict has been used as a basis for number of models and strategies for teaching for conceptual change. Simple presentation of chemistry concepts is usually not sufficient for learners to change their thinking about how the world works.

2.4.8.2 Analogies

Analogy refers to comparison of structures between two domains. According to Bozkoyun (2014:14), analogy is used as an explanatory tool by putting new concepts and principle into familiar terms. It serves a creative function when it stimulates the solution of existing problems, the identification of new problem and the generation of hypothesis. Calik et al. (2014:432) have shown that the use of a pictorial analogy can facilitate the learners' understanding of the effect of concentration on chemical reaction rate, and can help in misapplying of the relationship between concentration or temperature and the rate of reaction. Analogy-assisted change texts have also proven to be the most effective method in eliminating or overcoming learners' misconceptions regarding reaction rate (Kolomuç & Tekin, 2015:85). An analogy is a powerful explanatory tool that facilitates the learners' construction process on the grounds of concepts that are already available. Studies about analogies in science education have shown that analogies cause a significantly better acquisition of scientific concepts than the traditional instruction, and help students integrate knowledge more effectively.

2.4.8.3 Visualisation (computer-aided instruction)

The use of computer animation may develop learners' understanding of the related concepts and may be able to answer conceptual questions about particulate phenomena in a way that is more scientifically accepted (Calik et al., 2014:432). The use of animation has great potential to facilitate the teaching of difficult and abstract science concepts, because animation can help learners to imagine chemical phenomena at sub-microscopic level. According to Kolomuç and Tekin (2015:85), the use of package software for computer assisted teaching is one of the best methods to overcome misconceptions and replace them with the scientific ones. Computer animations allow learners to make links between symbolic concepts and process, or between chemical concepts and phenomena. According to Ortiz (2019:35), animations that make abstract concepts or phenomena concrete, provide opportunities for learners to improve their creative thinking, to focus on probable variations and to try out these variations. The computer animation could be used in conjunction with chemistry

demonstrations, because the use of animations helps learners to visualise how complex dynamic chemical processes take place at sub-microscopic level.

2.4.9 Factors affecting rate of chemical reaction

2.4.9.1 Effect of Temperature

According to Kirik and Boz (2012:6), most of the students could make correct interpretations on a curve related to the effect of temperature on reaction rate, but some students held a misconception (with little reasoning) that the higher the temperature is, the more the amount of the products are formed. Most chemical reactions occur faster at higher temperature and slow down as the temperature decreases. Temperature is the most important factor in making the reaction go faster. As temperature increases, the molecules move faster and are more likely to collide hard enough with other molecules to break the chemical bonds (Karsli & Ayas, 2014:665). The students' difficulties in studying the effect of temperature on the reaction rate are that students do not understand why, when the temperature is increased, collisions among particles are more frequent. There are also students who hold a belief that if the temperature is increased then the activation energy is greater so that the reaction rate becomes faster. According to Calik et al. (2014:433), most students held a misconception that an increase in temperature does not affect or change the rate of exothermic reaction, and that a rise in temperature would not affect the rate of reaction as it is independent of temperature.

2.4.9.2 Concentration

Calik et al. (2014:433) examined the students' understanding of the effect of increase in concentration of reactants in a chemical reaction, and observed that most students held a misconception that a change in concentration does not affect reaction rate. Students expected a higher rate from increasing the concentrations of the reactants. Kirik and Boz (2012:6) examined the students interpretation of the curve related to the effect of increase in concentration on reaction rate. They observed that most of the students could conclude that the reaction in which huge amounts of the product formed per unit

time is the fastest, though some students were of the view that the fastest reaction produces more products. According to (Karsli & Ayas, 2014:665), an increase in concentration increases the rate of chemical reaction. The students' difficulty in understanding the concept of the effect of concentration on the reaction rate is that students cannot explain the relation between reactant concentration and collision theory. For instance, such students argue that reaction rate is proportional to the concentration of reactants. The collision theory explains that the more molecules are crammed into a space the more likely that they are to collide.

2.4.9.3 Catalyst

Kirik and Boz (2012:6) indicated that students understand the effect of catalyst on reaction rate, and they could correctly interpret the curve related to the rate of reaction. Misconceptions still prevailed, as some students believed that catalyst gives energy to the reaction, and so increases the activation energy or the reaction rate, and that a catalyst increases the average speed of the molecules. A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the reaction. Calik et al. (2014:433) examined the students' understanding of the effect of catalyst and concluded that many students confuse the reaction intermediate and the function of the catalyst. Misconception held by the students was that catalyst does not participate in the reaction but only effects reaction by increasing reaction rate. Karsli and Ayas (2014:665) indicated that a catalyst facilitates a chemical reaction by decreasing a collision force required to break molecules apart to form new molecules. It was also found that students' difficulties in understanding the role of catalyst in accelerating reaction rate are that students are wrong in understanding the relationship between catalyst and activation energy. Students understand that the addition of the catalyst can increase the activation energy so that the reaction rate is faster.

2.4.9.4 Surface area

Kirik and Boz (2012:6) have shown that students understand that increase in the surface area increases the number of collisions so the rate of reaction increases by interpreting the visual representation of the reaction. Some students were confusing

melting with dissolving, which is like comparing a physical event with a chemical reaction. Students have also shown that a crumbled substance moves and react faster than a big piece of substance. When the reactants are present in different phases it is the surface area that determines the rate of reaction. Karsli and Ayas (2014:665) indicated that in reactions between reactants that are in different phases, as the surface area of the solid is increased there are more of gas or liquid to collide with the surface of the solid. The surface area can be increased by making the size of the particles smaller by grinding. According to Calik et al. (2014:433), common misconceptions held by most students are that to increase the rate of any reaction, the surface area of the reactants can be increased. Students incorrectly define the surface area on the reaction rate material because most students are still confused with the definition of surface area on the subject of mathematics. The concept of a true surface area is a material or particles of smaller size having a larger touch surface area so that the reaction is faster.

2.4.10 Reflections on research question and objectives

The research question to this study is “to what extend do misconceptions in reaction rate affect the conceptual learning abilities of the learners?” This is relevant and timeous as most learners and prospective teachers still show a lot of misconceptions regarding factors affecting reaction rate. Most literature shows that these misconceptions do affect learning and have a drastic negative impact on learners’ achievement. Most learners drop out of school because they do not cope with the complexity and abstractness of chemistry. The objective of this study is to identify the misconceptions learners have regarding reaction rate as a topic, and address the misconceptions using suitable strategies. Each misconception has its own nature and its development depends on several factors, including social environment learners interact with prior to formal education.

Research were conducted worldwide in trying to address these learning challenges and they have shown that no single scientific method or technique seemed to be relevant and sufficient to overcome misconceptions from different learners in different contexts (Marumure, 2014:1). These studies revealed that the models had a positive effect on

the learning process since they provided students the opportunity to experience from the first hand, allowed the students to visualise the events more accurately (Okumus et al., 2019:158). The learners' personal interpretation of the environment seemed to be the major contributing factor in the building of misconceptions. Several conceptual change methods were suggested, including but not limited to computer animation, analogy, conceptual mapping, worksheets, and experimental activities for improving learners' process skills. It also stated that the models provide solutions to problems, allow it to fill the information gap in the mind, and facilitate constructing and transferring of information (Evagorou et al., 2015:3).

2.4.11 Prospects of teaching reaction rate at school

Chemistry education was introduced in schools to create opportunities for learners to better understand the world around them. It provides knowledge and expertise for learners to take care of the environment and its surroundings. The aim is to produce learners who are scientifically orientated, can pursue careers that are science related, contribute to the economy and the development of the country, and become fully fledged members of the scientific community. The learners should understand how the systems are interconnected and how the world works. Scientifically literate individuals can more effectively interpret information, solve problems, make informed decisions, accommodate change, and achieve new understandings.

According to Koretsky (2020:105), the use of everyday life context has been seen as one way to raise learners' interest in science and to educate scientific literate citizens. To promote a rational, achievable approach to developing scientific literacy among future citizens, it is crucial to recognise how students learn, how science can best be taught, and how learning can be assessed (Manitoba Education Foundation, 2014:3). Students are curious, active, learners who have individual interests, abilities, and needs. They come to school with prior knowledge and various personal and cultural experiences that generate a range of attitudes and beliefs about science and life, and connections between these realms (Kariper, 2014:606).

Koretsky (2020:106) indicated that it is through effective teaching practices where learners are engaged actively in the learning process that promotes the achievement of intended objectives of producing scientific literate citizens with minimum misconceptions of chemistry concepts, especially on rate of chemical reaction. Bozkoyun (2014:30) has shown that many learners come to the class with their own conceptions of natural phenomena that are not consistent with scientific explanation. Misconceptions or conceptual difficulties of learners are potential barrier or risk to academic success of learners in science. Ahiakwo and Isiguzo (2015:113) indicated that the impact of teaching is evidenced in the performance of the learners. It is in this regard that it is suspected that there could be a link between a growth in a science education project and the performance of science students.

2.4.12 Summary of review of related literature

Having identified these misconceptions, strategies will be put in place to overcome alternative conceptions and replace them with conceptions agreed upon by scientific community, viz: conceptual change, a variety of methods have been used, laboratory activities, analogy-assisted change texts, group discussions, use of basic materials, and use of package software for computer-assisted teaching (Cheng & Gilbert, 2017:1). The use of animations has great potential to facilitate the teaching of difficult and abstract science concepts, because animations and models can be used to help students to imagine chemical phenomena at sub-microscopic level, and also observe the practical part of the topic under discussion. It was shown that it is necessary to design a student-centred teaching strategy to teach this abstract concept (reaction rate), as it forms a basis for all chemistry lessons at secondary school.

Evagorou et al. (2015:4) showed that correcting misconceptions requires that learners are aware of the misconception and dissatisfied with it, and that a replacement concept is available that is intelligible, plausible, and applicable. Evagorou et al. (2015:4) have shown that the alternative conceptions that students have constructed to interpret their experiences have developed over an extended period of time; one or two classroom activities are not going to change those ideas. Studying science involves

comprehending the concepts that shape science curriculum, and it is important for the teachers to know how the learners interpret these concepts. This mean that it is important for the researcher to also suggest the most efficient and effective ways for the learners to learn, apart from only providing insight into the most common learners' conceptions that occur at different ages.

It is important to understand the learners' misconception and that it is not easy to eliminate misconceptions by applying conventional methods. As concluded by Karsli and Ayas (2015:664), learners misunderstanding of concepts of reaction rate generally originated from experiences in everyday life. They further noted that teachers should be aware of learners' prior knowledge and misconceptions on reaction rate because they are strong predictors of learners' achievement. The learners should be guided during the learning process to make sense of experiences and to develop concepts into a coherent and consistent framework of knowledge (Karsli & Ayas, 2015: 664). According to Hanson (2020:73), they often fail to identify both obvious and overt alternative conceptions upon which students build knowledge. If they ever identify these alternative conceptions (or herein also referred to as misconceptions), they disregard them or fail to find appropriate strategies for remediation.

This means that teachers must commit themselves to assist learners to understand and not only to cover the syllabi. Less guidance or no guidance during learning is usually less effective than enough guidance, there is also the possibility to give effect to such students acquire knowledge is incomplete, causing misconceptions (Pikoli, 2020:3). The learners have to actively involve themselves by making sense out of new concepts through their existing knowledge. Pikoli (2020:2) has shown that symbolic representations were handed to leaners themselves to understand it without the guidance and direction of the teacher. Misconceptions can only be remedied if learners directly examine their own theories and confront their shortcomings. Ortiz (2019:33) showed that learners need to transform instructional language or materials, which the teachers use in the chemistry classroom into meaningful representations.

Many researchers have indicated their personal observations made during supervision of prospective teachers (teacher trainees or pre-service teachers) on the field for over ten years, that there is a gap between what these prospective teachers know in theory, and what they have to translate in practice when they have to act as facilitators to help their learners to restructure entire schemata (Hanson, 2020:73). They fail to translate technological, content, and pedagogical theories learned in school into realistic practical skills to help their own students to construct knowledge in a professional manner (Hanson, 2020:73). Data gathered showed that about a quarter (that is three) of these trainees, who were also practising teachers, could not clearly explain what alternative conceptions (herein also referred to as misconceptions) were (Hanson, 2020:77). They had varied ideas about the concept of 'misconception'. Trainee T7 implied in her answer to 'what alternative conceptions were' that, if students did not understand a topic then it implied that they had misconceptions. That was quite vague. T1 said that when students are confused, then that could be explained as evidence of misconceptions.

2.5 KEY FINDINGS INFORMED BY LITERATURE

The study revealed that the performance of learners in Physical science particularly rate of reaction is impacted by several misconceptions learners held. Some of the misconceptions seemed to have been in the learners' memories for quite a long time as they resulted from the learners' interaction with their immediate world and some other learning materials which did not provide adequate information. The study also found that language of instruction (English) is a problem to most of the learners in areas because they are unable to understand and interpret the questions as expected. Most schools do not have functional laboratories, therefore learners are unable to perform experiments and use models to enhance comprehension of the topics.

2.6 SUMMARY OF CHAPTER

Misconceptions are obviously not spontaneous ideas. They develop through many factors from both inside and outside the classroom context. Another factor pointed out by some literature is the home language of the learners. For learners to assimilate the scientific conceptions, they first translate them into their home languages, which in most

cases cause misconceptions. Science in itself is a language that should be understood as it uses scientific interpretations. More research has been done in an attempt to overcome misconceptions, several scientific methods or techniques were used to address these learning hinderers, and no single technique was found to be sufficient and efficient enough to eliminate the misconceptions. It can be concluded that more scientific research still needs to be done beyond this level to address the learners' misconceptions. Focus should not only be in the classroom context ,but also in the social environment where learners are first exposed to science, because the pre-knowledge which learners bring to the classroom that makes sense to them, is based on their daily life experiences and may not match the science context, and therefore may be wrong.

CHAPTER 3

RESEARCH METHODOLOGY AND DESIGN

3.1 INTRODUCTION

In this study the researcher used a mixed method approach. A mixed method research is a study in which the researcher collects and analyses data, incorporates the findings, and draws conclusions using both qualitative and quantitative approaches in a single study (Bidi, 2016:58). The qualitative method was important because it has shown the extent to which the learners understand the concepts, principles, procedures, and scientific knowledge. The quantitative method provided information from the number of the learners participated in the study. The purpose is to have quantitative data, and to check the reliability of learners' answers to several questions (Bidi, 2016:58). The choice of this approach is relevant to the study as it aims to explore the qualitative research as a method used when direct observations or interviews are not possible (Üce & Ceyhan, 2019:203).

3.2 RESEARCH APPROACH AND DESIGN

3.2.1 Research approach

In this study, a mixed method research approach was used. According to Fahmi and Irhasyuarna (2017:55), mixed method research is an approach to inquiry that combines or associates both qualitative (use of surveys and experiments) and quantitative forms (interviews). It involves philosophical assumptions, the use of qualitative and quantitative approaches, and the mixing of both approaches in the study. The quality of a study depends on the consistency between the research questions, research methods, methods, processes of data collection, and data analysis (Bidi, 2016:57). Thus, it is more than simply collecting and analysing both kinds of data, it also involves the use of both approaches in tandem so that the overall strength of a study is greater than either a qualitative or a quantitative study. Mixed methods research was developed as a result of pragmatism as this worldview is not committed to any one system of philosophy and reality. According to Fahmi and Irhasyuarna (2017:55), it has given the

researcher that freedom of choice and does not see the world as an absolute unity. In this study, the researcher used a sequential mixed methods research design.

This design was used mainly to elaborate the findings of one method with the other. As this study was carried out in two phases, the first phase involved a quantitative method, which was used to test a theory or concept. In the second phase, the qualitative method was used in an attempt to explore and give a thorough understanding of the individual learners' conceptual development. A sequential explanatory design, which was used, is illustrated as follows:

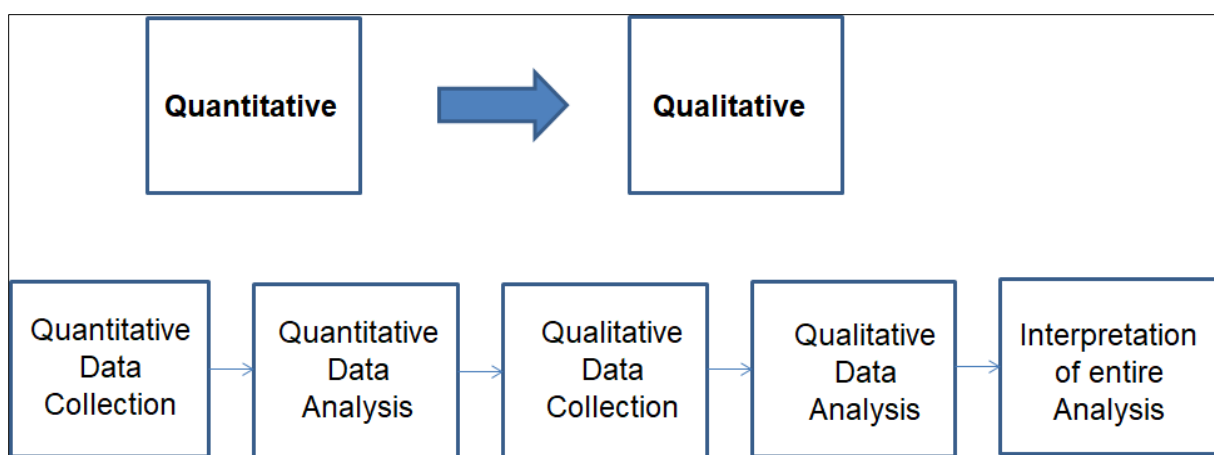


Figure 3.1: Sequential explanatory design

3.2.2 Research design

In this study, the researcher attempted to identify the cause of poor learners' performance in Physical sciences. The researcher assessed the effect of misconceptions with regard to the rate of reaction as it forms basis of all subsequent topics in science. A reaction rate concept test and interview questionnaire were designed and given to the Physical science teachers and the Curriculum advisor in the circuit to correct, adapt and validate the credibility of the questionnaire before it was administered to the learners. The questionnaire consisted of 10 items compiled from the textbooks currently used in schools with four possible answers to choose from. Learners were divided into control and experimental groups. This study was based on the Conceptual Change Approach. The experimental group was then taught about factors

affecting reaction rate by the researcher to clarify misunderstandings and to minimise or eliminate misconceptions detected in most learners' responses from the pre-test. Semi-structured interviews were conducted with the 20 learners from the experimental group to validate the data collected through the questionnaire, and for the researcher to better understand the learners' conceptual framework. For the purpose of this study, both the quantitative method and the qualitative method (mixed method approach) were used.

3.3 RESEARCH PARADIGM

The study was an exploratory type within the advocacy/preparatory worldview. The researcher believed that learners' poor performance was caused by misconceptions which learners acquired during informal and formal education. Realism Paradigm should also be considered when dealing with misconceptions in reaction rate because some exist not as a result of human error, but because of cognition of external objects not perceived. Schools which do not have laboratories should strive to have spare classroom where learners can perform experiments to clear misconceptions. Conceptual change theory is defined as a process of learning science in a meaningful way that requires the learner to rearrange and replace existing misconceptions to accommodate new conceptions (Bidi, 2016:28). Pragmatic Paradigm showed that modelling and hands-on experimentation stimulate learning because learners grasp effectively through seeing and touching. Bidi (2016:6) has shown that science education prepares learners to follow a career in science and become scientific literate citizens, as education depends on the humanitarian factor.

Evagorou et al. (2015:3) placed more focus on the process of modeling as a scientific practice, which includes the construction and use of models, the use of other representations, and the communication in the groups. The researcher has a strong belief that if the teaching of chemistry education took place with the aid of models, computer programmes, and experimentations, most learners would have developed an interest and pursued careers in sciences. It was noted that most learners have attitude towards Physical sciences and this made them to have less interest in the subject' Teachers should motivate, encourage and instil the spirit of positivism among the

learners to build their self- confidence. Ejidike and Oyelana (2015:607) pointed out that according to various theories; the key to success in any human endeavour is the desire of that person. The researcher realised that most of the learners participated in the study do not have interpretative skills. Instead, they attempted to switch the languages and during the course of translation misconceptions occurred. Because learners are not competent in expressing themselves in English as medium of instruction, their ability to think critically is compromised. Ejidike and Oyelana (2015:607) suggested that teachers require professional knowledge and professional teaching skills, as well as a broad base of general knowledge to perform instructional processes effectively.

3.4 QUALITATIVE STUDY

3.4.1 Population and Sampling

This survey was conducted by the researcher in person or by phone to check for the learners' understanding of the topic, and to verify their readiness to participate in the study. Hanson (2020:69) has shown that Ghanaian teachers identify and address their students' alternative conceptions, especially in the study of chemical equilibrium, through the use of face-to-face, telephone, and email procedures. This study was conducted within the borders of the Republic of South Africa with 92 Grade 12 learners in Limpopo Province, targeting the Zebediela cluster at Sebitja secondary school, Makgwading High, and Phalaggoro-Mothoa High in Lepelle 2 circuit. The research site was a secondary school in the rural area of Eastern Cape Province with a total number of 34 Grade 11 Physical Sciences learners (Bidi 2016:62). Sampling refers to a process of selecting a portion of the population to represent the whole population (Bidi 2016:62). The ages of the learners in both the control group and the treatment group ranged from 17 to 20 years.

3.4.2 Data Collection Instrument

The reaction rate concept test was administered to both control and experimental groups as Pre-test to check their level of knowledge with regard to rate of reaction. The test was marked and the marks recorded. (Bidi, 2016:60) has shown that quantitative

data in the study could be obtained through the use of questionnaires in the form of pre-test and post-test. The test results have shown the nature and source of the learners' misconceptions. These results also provided a full understanding of the learners' problem areas, and gave an opportunity to develop sound teaching and learning strategies aimed at addressing such misconceptions during the course of grasping new concepts.

Lessons were designed and presented to learners in the experimental group to enhance understanding and to address conceptual change conditions (Bidi, 2016:60) has shown the importance of teaching the learners before administering the Post-test. The Post-test was administered to the learners in the experimental group, marked and the marks were also recorded. Semi-structured interviews were also conducted with a few focus learners to gain a full view of the learners' thinking and understanding of how these misconceptions originate, and what influence they have had in their conceptual abilities. The initial step of this study is to survey some of the high schools in Banjarmasin, conducted interviews to teachers of chemistry lessons at school and learning process in the classroom (Fahmi & Irhasyuarna, 2017:55).

3.4.3 Data Analysis

Completed and returned questionnaires were scored, assigning numeric values or scores to the responses, cleaning data errors from the database, and the creation of a special variable where needed. Jusniar et al. (2020:1407) have shown that students who experience misconceptions were determined from the test by scoring. Findings obtained from RRCT were analysed, thus giving the researcher insight about the formation of misconceptions in learners' minds. Data analysis was done by finding the percentage of correct answers at each level for each item, and the percentage of answers to misconceptions for each category. The learners' concept knowledge in reaction rate as obtained from RRCT were analysed, and this has given the researcher an idea of misconceptions learners had. Michaliskova and Prokša (2018:1) have shown in their study that the results were analysed in terms of deeper insight into the students' understanding of the issue, and students' misconceptions were also identified.

3.5 QUALITATIVE STUDY

Wallen and Fraenkel (2013:17) indicated that the purpose of qualitative research is to understand a specific social situation, group role, event, or interaction. A phenomenological approach was used in this study to understand the participants' learning experiences as well as their sources of the different misconceptions that they displayed. Qualitative analysis criteria were used based on the answer patterns of students experiencing misconceptions. Research about the experiences was important in this study as it described the meaning or essence of a lived. In this phase, individual interviews were conducted with selected respondents who were involved in the first quantitative phase of the study.

3.5.1 Population and Sampling

The researcher conducted in-depth interviews with each participant in-person or by phone. Bidi (2016:109) has shown that interviews helped to clarify learners' misconceptions in a comprehensive manner. The learners were Sepedi speaking, doing English as their first additional language, which is also a language for teaching and learning. This means that the participants were not fully conversant in English, even if the study was conducted in English. Bidi (2016:24) showed that another common source of misconceptions is the language used on a daily basis. The sample consisted of twenty Grade 12 learners who took physical sciences as a subject. A purposive selection of the participants was done to enable the researcher to understand the research problem fully. Purposive sampling of schools was done by giving schools an equal chance of being selected.

3.5.2 Data Collection Instrument

In a qualitative research, data was collected through case studies, focus group, open-ended questions, and in-depth interviews. Interviews were agreed and interview schedules were made available to the prospective interviewee. An interview is a two-way communication in which the interviewer collects data by posing questions to the participants to learn about the participants' beliefs, ideas, behaviours, and opinions. The

researcher posed questions to gain a deeper understanding of the phenomenon under study. The purpose for using tests was to obtain the opinions of the learners and the existing knowledge learners have with regard to chemical change. The learners who took part in quantitative phase were used for the purpose of data collection. Data was collected through interviews and the researcher himself was considered to be a measuring instrument. The purpose for the interview was to obtain relevant information to address the research question.

3.5.2.1 Credibility

The credibility of the data was based on prolonged engagement with the participants, persistent observation of the participants by the researcher and peer debriefing. The data collected in this study is genuine, because it was collected from the participants themselves.

3.5.2.2 Transferability

Broader description of data assured that a larger scale of information was collected and could be exchanged for further analysis and to allow for further research.

3.5.2.3 Dependability

Inquiry audit was used to attest for the reliability data collected. The data is reliable, valid and have shown exactly what the learners knew and understood at the time the research was conducted.

3.5.2.4 Confirmability

Some misconceptions are persistent in nature, they may reflex despite audit trail was made. The data collected in this study remained the true reflection of the learners work and was in no way adjusted.

3.5.3 Data Analysis

A transcription of each individual and group interview was made. Transcriptions were organised in categories, reviewed repeatedly, and coded continually. The marks for the pre-test and the post-test were recorded in an excel spread sheet, tabulated, and categorised according to percentage and then displayed in the form of a graph. Learners' responses were coded and compared against each other. All the interviews

were coded manually for themes, audio-taped, and transcribed in writing. Qualitative data was analysed by counting the number of occurrence of codes of themes. All interview data were transcribed and their drawings were added to the transcripts for analysis. These themes and other related findings gave answers to the research question. Therefore, the analysis of this data was focused only on the misconceptions learners had with regard to reaction rate in chemistry. These categories are: 1. Sound understanding, 2. Partial understanding, 3. Partial understanding with certain misconception, 4. Specific alternative concepts, and 5. No understanding.

Table 3.1: Questions in the RRCT and the concepts investigated

This test was designed to measure and evaluate the learners' learning of rate of reaction in chemistry course. It consists of 10 multiple choice questions.

Make a cross on the correct alternative next to the corresponding number such as 1. F

Question Heading	Concepts Investigated
<p>Q 1. Related to reaction rate which one of the following statements is correct?</p> <p>A. Reaction rate is equal to changes of concentration of reactants (or products) per unit time.</p> <p>B. All the chemical reactions occur vigorously.</p> <p>C. Reaction rate is equal to time period between reaction starts and ends.</p> <p>D. Reactions go on with their initial rate.</p>	<p>Defining the rate of reaction.</p>
<p>Q 2. $A(g) + 2B(g) \rightarrow 2C(g) + 3D(g)$ reaction is given. During this reaction, the reaction vessel is heated. According to this, which of the following statement(s) is (are) correct?</p> <p>I. Reaction rate increases.</p> <p>II. Heat of reaction increases.</p> <p>III. Amount of product increases.</p> <p>A. Only I</p> <p>B. B. Only III</p> <p>C. I, II</p>	<p>Explaining the effect of temperature on the reaction rate.</p>

D. I, II, III	
<p>Q 3. Which one of the following statements is correct related with the effect of temperature on reaction rate?</p> <p>A. Rate of exothermic reactions decreases when temperature increases.</p> <p>B. Temperature increases the reaction rate by lowering the activation energy.</p> <p>C. Temperature increases the reaction by giving heat.</p> <p>D. Temperature increases the reaction rate by increasing the kinetic energy of the molecules.</p>	<p>Explaining the relationship between temperature and the kinetic energy of the molecules.</p>
<p>Q 4. For endothermic and exothermic reactions, which one of the following statements is correct?</p> <p>A. All endothermic reactions occur very slowly.</p> <p>B. All exothermic reactions occur rapidly.</p> <p>C. It is very difficult to initiate endothermic reactions.</p> <p>D. Rate of exothermic reactions increases with temperature</p>	<p>Explaining that when the rate of endothermic reaction increases, the rate of the exothermic reaction also increases.</p>
<p>Q 5. Which one(s) of the statements is (are) correct?</p> <p>I. Catalyst does not participate into the reaction.</p> <p>II. Catalyst only affects reaction by increasing the rate.</p> <p>III. Catalyst changes the value of activation energy.</p> <p>A. Only I</p> <p>B. Only II</p> <p>C. I, II</p> <p>D. I, II, III</p>	<p>Explaining the effect of a catalyst on the reaction rate.</p>
<p>Q 6. If we mix reaction vessel, the reaction occurs rapidly. What is the reality behind this fact?</p> <p>A. The activation energy decreases.</p> <p>B. Average kinetic energy of the molecules increases.</p> <p>C. Molecules are broken.</p> <p>D. Number of fruitful collision increases.</p>	<p>Explaining that when the stirring results in effective collisions which influence a reaction to take place.</p>

<p>Q 7. $2A(s) + B(s) \rightarrow 3C(s) + 2D(g)$</p> <p>Which one of the following changes below increases absolutely the reaction rate?</p> <p>I. Increasing the surface area of reactant. II. Increasing the temperature. III. Increasing the concentration of B liquid.</p> <p>A. Only I B. Only II C. I, III D. I, II, III</p>	<p>Explaining the effect of temperature on the reaction rate.</p>
<p>Q 8. Which one of the following statements is correct related with the activation energy?</p> <p>A. It is a kind of heat energy. B. It is the top point in number of molecules and kinetic energy graph. C. It is a kind of kinetic energy for reactant to form product. D. It does not affect reaction rate.</p>	<p>Explaining the relationship between the activation energy and the rate of reaction.</p>
<p>Q 9. $A(g) + B(g) \xrightarrow{C} D(g) + E(g)$</p> <p>If C is the catalyst of the reaction. What is the function of C in the reaction?</p> <p>A. Speeding up the molecules. B. Decreasing the activation energy. C. Facilitating molecules to react. D. Increasing the amount of product.</p>	<p>Explaining the role of a catalyst on a chemical reaction.</p>
<p>Q 10. Related with activated complex, which one of the following statements is wrong?</p> <p>A. It is the state of highest potential energy. B. All the molecules in the state of activated complex turn into product. C. It is a necessary energy to move up energy of activated complex. D. Molecules in the state of activated complex are rearranged to form product molecules.</p>	<p>Explaining that not all of the reactants are turned into products.</p>

Table 3.2: Categories of comprehension used to analyse the answers in the RRCT

Cronbach`s alpha	Internal consistency
$a \geq 0,9$	Excellent
$0,9 > a \geq 0,8$	Good
$0,8 > a \geq 0,7$	Acceptable
$0,7 > a \geq 0,6$	Questionable
$0,6 > a \geq 0,5$	Poor
$0,5 > a$	Unacceptable

3.6 TRUSTWORTHINESS

After receiving an approval from the CUT FRIC, a letter was written to the Education Department requesting permission to conduct in some schools in the circuit. Upon receiving permission from the department, letters were written to Principal as well as the Governing Body of the school asking for permission to conduct research in the school. The circuit manager was also informed as five of the secondary schools in his circuit were part of the pilot process. In cases of school names, the researcher used SA for School A, SB for School B, SC for School C, SD for School D, and SE for School E. Each and every learner in each school was given a code to use instead of his or her real name. For learners' names, the researcher used Aa for learner 1, Ab for learner 2 in School A, Ba for learner 1 in School B, Bb for learner 2 in School B, Ca for learner 1, Cb for learner 2 in School C, and Da for learner 1 in School D, Db for learner 2 in School D, Ea for learner 1, Eb for learner 2 in School E. The researcher ensured confidentiality of information from the participants taking into account the fact that the decision for considering the anonymity of the participants finally rested with themselves.

3.7 VALIDITY AND RELIABILITY

3.7.1 Reliability

Reliability is the internal consistency of items on a quantitative instrument, the stability of the test over time, as well as whether consistency was applied in the administration and scoring of the test. Reliability in quantitative research refers to the repeatability of the instrument and test administration in the study, while in qualitative research reliability refers to the consistency of the researcher's role (insider, participant, and outsider), the data collection methods, data recording and interpretation of the participants' meanings from the data by the researcher (Bidi, 2016:72). For each item in RRCT, there is only one correct response. It is also important that the wording of the question is in such a way that it is clear and understandable. To ensure reliability in this study, the researcher administered the same test twice to the same sample (Bidi, 2016:72). The research questions were administered on the same group of learners who participated in the study. The study was carried out on one group.

3.7.2 Validity

Bidi (2016:72) stated that validity refers to the appropriateness, meaningfulness, and usefulness of the specific implications researchers make, based on the data collected using an instrument. A test should measure what it is meant to measure. The topic under study is relevant to the Grade 12 learners, and the language used is also at the level of the learners. Furthermore, the instrument (RRCT) and equipment (acids, salts, mass meter, and thermometers) used were given to the local CA for testing before and after the execution of the study. Pikoli (2020:1) posits that the validity of the tests should be evaluated by expert validator. The RRCT was only used to check the learners' alternative concepts and was regarded as a valid tool in this study. After the RRCT was developed, it was piloted in five neighbouring schools in the Zebediela area, which meant that each item got 100 responses. The findings of the pilot study were used to refine the instrument. The researcher distributed the questionnaires to five colleagues for review, and four of the colleagues hold master's degrees (Marumure, 2014:35).

3.8 ETHICAL CONSIDERATIONS

The rights of the learners (participants) were protected by:

- The researcher tried by all means to minimise risk to participants by using procedures that did not unnecessarily expose participants to risk, and the proposed study did not discriminate among the individuals in the population (equitable selection).
- Signing a written consent form before engaging in the research and the research objectives were attached to the consent form so that the participants can understand the purpose of the research.
- Informing the participants about the data collection methods and activities, as well as how the data was utilised and analysed.
- Informing them that taking part in the research was voluntary and they could withdraw at any time during the research process and they would not be penalised.
- Ensuring that the research was not meant for any other purposes, except testing participants' knowledge on reaction rate.
- Ensuring that the vulnerable individuals were protected (disabled and economically disadvantaged) and that data was monitored to ensure the safety of the participants.

3.9 LIMITATIONS OF THE STUDY

From 23 Secondary Schools in the Zebediela cluster, only 5 schools were sampled and out of the 3 circuits, only 1 circuit was sampled for the study. The study was limited to 5 schools and 1 circuit in the Zebediela cluster, Capricorn South District. The researcher used random sampling to select the schools.

3.10 DELIMITATIONS OF THE STUDY

The study was conducted in the circuit of the Capricorn South District of the Limpopo Province, and involved 5 schools totalling enrolment of 95 Grade12 learners, a circuit

based CA, and interested science educators. This placed a limit on the generalisability of the findings to all schools in the cluster and the district.

3.11 SUMMARY OF CHAPTER

This chapter dealt with a mixed method approach in research, population and sampling, data collection and data analysis, trustworthiness of data and ethical considerations. In the next chapter, emphasis is on presentation and interpretation of data.

CHAPTER 4

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

4.1 INTRODUCTION

This chapter provides a report on findings in which the views and ideas of participants were constructively consolidated in terms of their understanding of factors affecting reaction rate. There were a few aspects observed during the pilot study, and these are reported in this chapter. Data gathered was quantitatively and qualitatively analysed.

4.2 QUANTITATIVE DATA

The participants in this study are all from Quintile 1 Schools, which by nature have no adequate resources and are not much exposed to the outside world, or have a narrow knowledge system. All the participants in the pilot study are from the same circuit. A total of 92 participants were involved in this study and all of them returned their questionnaires.

4.2.1 The participants' type of schooling

All the participants in this study are full time Grade 12 learners for academic year 2021. The participants have poor socio-economic backgrounds, which may negatively impact on their academic performance.

4.2.2 Number of learners per class

Table 4.1: Number of learners per class

School	No of learners per class	%
School A	20	21.7
School B	18	19.6
School C	16	17.3
School D	18	19.6
School E	20	21.7

Total	92	100
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4.2.3 Qualifications of teachers and job status

Table 4.2: Qualifications of Teachers and Job Status

School	Qualification type	Job status
School A	PGCE	Permanent
School B	PGCE	Permanent
School C	Diploma	Permanent
School D	Bed	Permanent
School E	Bed	Temporary
Total	5	

The qualifications of teachers play an important role in clarifying the misconceptions and challenges that learners are faced with in teaching and learning contexts. Qualifications measure the level of expertise teachers have to address learners' poor academic performance. From the five selected schools it was found that one teacher had a Diploma in teaching (STD), two deviated from other fields and did Postgraduate Certificate in Education (PGCE), and the other two are qualified science teachers.

4.2.3.1 The role of teachers in the study

The role of teachers in this study was to organize learners and collected consent forms from the learners. They also organized venues at their respective schools in which test was to be administered, assist the researcher in distributing questionnaires and collecting answer scripts from the learners after writing. They were also interviewed to get a sense of what challenges they come across regarding rate of reaction.

4.3 FINDINGS

Tables were used to record the number of learners achieved in each question against those who have partially or incorrectly answered the rate of reaction concept test (RRCT) questions (learners still having misconceptions).

Table 4.3: Pre-test scores and the percentages

Questions	No. of learners answered correctly	Percentage	No. of learners answered incorrectly		Total Percentage
	f	%	f	%	
Q 1.	11	55	9	45	100
Q 2.	2	10	18	90	100
Q 3.	3	15	17	85	100
Q 4.	10	50	10	50	100
Q 5.	11	55	9	45	100
Q 6.	5	25	15	75	100
Q 7.	7	35	13	65	100
Q 8.	13	65	7	35	100
Q 9.	3	15	17	85	100
Q 10.	4	20	16	80	100
		345		655	
		34.5%		65.5%	100%

Table 4.4: Post-test scores and the percentages

Questions	No. of learners answered correctly	Percentage	No. of learners answered incorrectly		Total Percentage
	f	%	f	%	
Q 1.	15	75	5	25	100
Q 2.	10	50	10	50	100
Q 3.	8	40	12	60	100
Q 4.	10	50	10	50	100
Q 5.	11	55	9	45	100

Q 6.	7	35	13	65	100
Q 7.	7	35	13	65	100
Q 8.	16	80	4	20	100
Q 9.	10	50	10	50	100
Q 10.	12	60	8	40	100
		530		470	
		53%		47%	100%

The details of the answers given by the learners to the questions in the RRCT test are depicted below.

4.4 ANALYSIS OF DATA

4.4.1 Quantitative Analysis

Question 1

A total of 55% (11) of the learners answered Question 1 correctly. The rate of reaction was defined as changes of concentration of reactants (products) per unit time, while 45% (9) of the answers showed that some learners still have partial comprehension of the concept as a result of alternative conceptions.

Question 2

Only 10% (2) of the learners answered with full comprehension. The effect of temperature on the reaction vessel is that it increases the reaction rate by providing the reactants with sufficient energy required to enable them to collide with one another. In the 90% (18) of learners who got it wrong, some learners showed partial comprehension and others showed alternative conceptions all together. These groups of learners have knowledge that is built on alternative conceptions, which hinder the assimilation of the accepted scientific concepts.

Question 3

A total of 15% (3) of the learners answered Question 3 correctly, showing full comprehension of the concept. The role of increase in temperature is to increase the reaction rate by increasing the kinetic energy of the molecules, while 85% (17) of the learners got it incorrect. This showed that some learners still have alternative conceptions while others showed that they have partial comprehension of the concepts. There were statements such as “the temperature increases the reaction by giving heat”, “temperature increases the reaction rate by lowering the activation energy” and “rate of exothermic reaction decreases when temperature increases”.

Question 4

Only 50% (10) answered Question 4 correctly, and another 50% (10) of the learners shown that learners partially understand the concepts and that the learners still alternative conceptions. There were statements such as “all endothermic reactions occur very slowly”, “all exothermic reactions occur rapidly” and that “it is very difficult to initiate endothermic reactions”. All these statements showed that some learners partial understanding reaction rate. Some learners indicated that it is difficult to initiate an endothermic reaction, which clearly showed that they do not have an understanding of the effect of temperature on the reaction rate. These learners failed to realise that both the forward and the reverse reactions form a system. This means that when the rate of the forward reaction increases, the rate of the reverse reaction also increases.

Question 5

Only 45% (9) of the learners' responses were wrong on Question 5, and 55% (11) of the answers were correct. Some learners still do not understand the role of a catalyst in a chemical reaction. Others indicated that a catalyst does not participate in a reaction, while it actually affects the chemical reaction by increasing the rate. Some learners indicated that a catalyst changes the activation energy, but failed to indicate whether the value of the activation energy is decreased or increased. In actual fact, a catalyst

provides an alternative mechanism for the reaction and lowers the activation energy, and thereby increases the reaction rate.

Question 6

While 25% (5) of the learners' answering Question 6 correctly were in the FC category, 75% (15) of the answers were in the category of PC and AC as Table 4.4 shows. Most learners confused the mixing of the reaction vessel with the heating of the container (reaction vessel). The learners indicated that when the contents of the reaction vessel are mixed, the activation energy of the system decreased and that the average kinetic energy of the molecules increased or the molecules are broken. In fact, when the contents are mixed by stirring or shaking, the number of effective and fruitful collisions were increased which led to a chemical reaction to take place.

The mixing of the reaction vessel also helped in re-arranging the molecules into more favourable positions that might have led to chemical reaction.

Question 7

A total of 35% (7) of the learners' responses on Question 7 are in the FC category and 65% (13) of the responses were wrong. Most of the learners indicated that if the surface area of one of the reactants is increased then the reaction rate is increased. Most learners seemed to have overlooked the states or phases of the reactants. Others said that the reaction rate can be increased by increasing the concentration of one of the reactants in liquid form, but none of the reactants was in the liquid form.

Question 8

Only 65% (13) of the answers for Question 8 were in the FC category, which clearly indicated that most learners understood what activation energy is, while 33% (7) of the learners' responses were incorrect. Some learners related the activation energy to heat energy and the number of molecules, and others indicated that activation energy does affect the reaction rate. Some learners have shown no understanding of the role played by the activation energy to influence reaction rate. From the learners' responses, it was

clear that some learners confused the activation energy with the heat energy which arises when the reaction vessel is heated.

Question 9

Only 15% (3) of the learners' responses for Question 9 were in the FC category and 85% (17) of the learners' responses showed partial understanding of the concept, and other responses consisted of alternative conceptions. Those who answered correctly showed full understanding of the function of a catalyst in a chemical reaction. Thus, the catalyst decreases the activation energy by providing alternative mechanism for the reaction. Learners with partial comprehension indicated that a catalyst facilitates the molecules to react, while others with alternative conceptions indicated that the catalyst would only speed up the molecules and increase the amount of the product formed. These learners confused the role of the catalyst with increase in concentrations of the reactants. Of course, if the concentrations of the reactants are increased then more products will be formed.

Question 10

A total of 20% (4) of the learners answered Question 10 correctly in the FC category, while 80% (16) of the learners' responses were incorrect and have shown a few misunderstandings of the question. The question requested the learners to choose the wrong alternative with regard to the activated complex. There were statements such as the activated complex is "the state of the highest potential energy", "it is necessary energy to move up energy of the activated complex" and that "molecules in the state of the activated complex are re-arranged to form product molecules". All these statements are true for the activated complex. These learners assumed that all the molecules in the activated complex turn into products, which is totally incorrect because the molecules do not usually react in the correct proportion and some of the reactants, are limited.

4.4.2 Qualitative Analysis

Table 4.5: Misconception detected from interviewed learners from experimental group

Concept	Detected misconceptions
Defining the reaction rate	<ol style="list-style-type: none"> 1. All chemical reactions occur spontaneously. 2. Reaction rate is equal to time between the point when the reaction starts and ends.
Explaining the effect of temperature on reaction rate	<ol style="list-style-type: none"> 1. Heat of reaction increases 2. Amount of products increases
Explaining the relationship between temperature and kinetic energy	<ol style="list-style-type: none"> 1. Temperature increases the reaction rate by lowering the activation energy 2. Rate of exothermic reaction decreases when temperature increases 3. Temperature increases the reaction by giving heat
Explaining the effect of a catalyst on reaction rate	<ol style="list-style-type: none"> 1. Catalyst does not participate in the reaction 2. Catalyst changes the value of activation energy
Explaining the relationship between the activation energy and the rate of reaction	<ol style="list-style-type: none"> 1. It is a kind of heat energy 2. It is a top point in number of molecules and kinetic energy graph 3. It does not affect the reaction rate

Having realised that 65.5% (13) of the learners are in a group of partial conception and alternative conception, a few learners were interviewed randomly to establish the origins and the types of the misconceptions the learners usually have, to design the correct remedial strategies to enhance conceptual change. These learners were also interviewed on questions which they got correct just to check whether they have full understanding of the principles of reaction rate, or maybe they were guessing as higher percentage of learners' responses shown many misconceptions (refer to Table 4.5).

The identified misconceptions by RRCT, and if this is examined, it can be seen that many learners are still having misconceptions.

Learner Ae

Question 1

When the learner was asked how s/he arrived at option 'C', the learner said, "verbatim", "I did not understand what the question meant and assumed that option 'C' was correct as it involved the time from the beginning to the end" In question 1, the levels of understanding of the learners concerning the concept of reaction rate were investigated. Even though most of the learners defined the reaction rate correctly, some misconceptions were observed. Some of the misconceptions that learners have are "Catalyst does not participate in the reaction" and "Catalyst changes the value of the activation energy".

These misconceptions resemble those identified by Calik et al. (2010). These misconceptions may result from the fact that learners confuse the rate of reaction with the time in which a reaction is completed. This might also have been done as learners study to pass a test or examination without understanding the concepts.

Question 2

In question 2, the learners were required to explain the effect of temperature on the reaction rate. From Table 4.4, it can be seen that 10% of the learners participated in the study got this question correct. This learner indicated that s/he thought that the question meant 'what happens to the products when the reaction vessel was heated. This learner had a misconception that temperature increases heat of reaction and that the amount of product increases. However s/he was very happy at the end of the face-to-face discussion with the researcher with regard to this question, because s/he was convinced that heating is related to increase in temperature and it increases the reaction rate. The learner seemed to have understood the role of heating the reaction vessel.

Question 5

The learner got this question correct and has shown full understanding of the concept tested.

“Verbatim”

“I chose option A, because I knew it from last year that a catalyst does have effect on the reaction rate, it only lowers the activation energy. I thought the question was referring to when the reaction is at equilibrium”.

This learner s/he misunderstood the concepts equilibrium and reaction rate and uses them interchangeably as synonyms of each other.

Question 6

This question involved the mixing of the contents of the reaction vessel. The learner indicated that s/he thought that when the contents are mixed, there is a certain amount of a chemical which is added into the reaction vessel and therefore decided to choose option B. This learner showed no understanding of the principles around the chemical reaction and the reaction rate, because mixing has nothing to do with addition of one of the reactants. By mixing obviously means that more effective collisions, which lead to a chemical reaction, are created. The learner shown no understanding of that initially, but was happy to realise that for reactants with different densities the denser reactant will remain at the bottom while a less dense one remains at the bottom. Then for the reactants to react, the reaction vessel needed to be mixed.

Question 7

With regard to question 7 (refer to appendix B) the learner did not consider the states of the reactants and said:

“verbatim”

“I did not notice that the reactants are all in a solid form and that one of the products is a gas. In fact I did not consider the phase or state of the chemicals involved”.

Question 9

When the learner was asked how s/he arrived at option A, the learner indicated that s/he overlooked the question statement and chose option A, which s/he did not read to the end as s/he was only interested in speeding up of the molecules. The learner thought that when a catalyst is added, then the speed of the molecules increases.

Question 10

The question requested the learners to choose the wrong statement with regard to the activation energy and the learner said:

“Verbatim”

“I did not understand the question and I thought the question was more related to the highest point of the potential energy. The researcher explained the question to the learner and the learner was happy to realise that in every chemical reaction there is a limiting reagent which means that not everything that forms an activated complex is turned into the products.

Learner Am

Question 2

The learner has chosen option D and when asked how s/he arrived at that, the learner indicated that s/he did not understand the question very well and thought the temperature also plays a role in the heat of reaction, and the amounts of product to be formed. The misconception is that the learner confused the heat of reaction with the temperature. The learner seemed to not understanding the role of temperature on the reaction rate.

Question 5

The learner was asked to define activation energy and related it to option D. The learner said:

“verbatim”

“I chose option D because when I looked at the definition of the activation energy in Grade 12 Oxford Successful, it was explained that a catalyst does not get used up but it lowers the activation energy of the reactants”.

Question 6

With regard to this question the learner said s/he has chosen option A because s/he thought the reaction is going to occur rapidly and the activation energy would decrease. When the learner was asked how he/she came to the conclusion that the reaction is going to occur rapidly, the learner indicated that s/he thought that every exothermic reaction occurs rapidly.

Question 7

The learner was asked to mention all the factors that may bring changes to the reaction (refer to appendix A) to increase the reaction rate. The learner included factors such as surface area and increasing the concentration of one of the reactants. S/he indicated that s/he chose option D, because s/he thought when s/he increases both factors the reaction is going to occur more rapidly and more products would be formed.

Question 8

The learner said s/he was very doubtful with option C, because s/he thought for molecules to react with one another they must be heated first and that is why s/he decided to choose option A. The learner seemed to not know what activation energy is and the role it plays on the reaction. Even though it is not increasing the reaction rate, it is the energy that is needed to start the reaction.

Question 9

When asked the learner was asked about the function of a catalyst in a chemical reaction, the learner indicated that s/he did not fully understand the question, and has just guessed that option A was the correct answer because it involved speeding up the molecules which s/he confused it with speeding up the reaction rate.

Question 10

The learner was asked to define the activated complex and defined it as correctly as the intermediate phase towards the formation of the products and thought that all reactants form products. The learner further indicated that s/he was not aware that not all of the reactants are turned into products.

“verbatim”

“I thought that once the two or more molecules are mixed together, they will finally be turned into products”.

Learner Ac

Question 1

The learner was asked to define reaction rate and still maintained that option C is the correct alternative, because it involved the total time from the beginning to the end of the reaction. The learner indicated that s/he thought that the question involved atoms because the reaction equation usually is balanced to make the atoms equal on both sides of the reaction. The learner showed a deep rooted misconception because s/he compared the number of atoms on both left and right sides of the equation and said nothing about decrease in concentration of the reactants and increase in concentration of the products as the chemical reaction proceeded. It was explicitly explained in detail to her/him that during the reaction reactants loses some of their molecules to contribute in forming new substances, and was delightful to acquire such knowledge.

Question 2

With regard to the effect of heating the reaction vessel, the learner indicated that s/he confused the heat of reaction with the amount of energy required to start the reaction and that when the whole reaction increases, the rate of reaction also increases. The learner showed no understanding of the effect of temperature on the reaction rate because s/he seemed to be mixing up things all together. The misconception detected was that the learner confused the reaction rate with the chemical reaction. The reality is that increase in temperature of the reaction vessel increases the reaction rate.

Question 3

The learner got this question correct and has shown full understanding of the concept and said:

“verbatim”

“I referred this from the pamphlet which was given to us in the classroom which stated clearly that when the temperature increases, the reaction rate increases by increasing the kinetic energy of the molecules”.

Question 4

The learner got this question correct and showed full understanding of the effect of temperature on reaction rate for both endothermic and exothermic reactions.

“verbatim”

“I am quite show that for endothermic and exothermic reactions when the temperature is increased, the reaction rates for both reactions increase”.

Question 5

The learner indicated that s/he had confused the word ‘participate’ with ‘used up’. The learner further indicated that s/he thought that when a catalyst is added in the reaction, it only speeds up the molecules. The fact is that a catalyst does participate in the

reaction by increasing the reaction rate without itself getting used up. The misconception here is that the learner does not understand the function of a catalyst in a chemical reaction and use the reaction concepts haphazardly as if they mean one thing.

Question 6

The learner got this one correct and showed full understanding of why should a vessel be shaken when a reaction proceeds and said:

“verbatim”

“I do fully understand that when a reaction vessel is mixed, the number of fruitful collisions that lead to a chemical reaction increases. So, more chances are created for a chemical reaction to take place”.

Question 7

With regard to this question, the learner indicated that s/he knew that the surface area, temperature, and concentration affect the reaction rate, but s/he did not consider the states in which the reactants exist. S/he indicate that s/he only looked at them as factors influencing the reaction rate without considering the states or phases of the reactants.

Question 8

The learner go it correct and had shown full understanding of the importance of activation energy in the chemical reaction and indicated that for atoms of the reactants to mix together, there must be a little amount of energy that allow them to do so. The learner said that s/he “knew that the activation energy is a kind of kinetic energy required for reactants to form products. He further said “this one I know it and understanding it fully”.

Question 9

When asked to give the function of a catalyst in the reaction, the learner indicated that a catalyst speeds up the molecules. This answer is similar to the one s/he gave in the questionnaire. From the questionnaire s/he indicated that s/he chose option A (speeding up the molecules), because it looked similar to speeding up the reaction rate.

Question 10

The learner was requested to re-look at the question in the questionnaire and said that s/he did not understand the question correctly and thought that the activated complex is more concerned with the energy to move it up. However, s/he chose the correct alternative but that was not what was required of him.

Learner At

Question 1

The learner was asked to define reaction rate and still maintained that option D is the correct alternative, because it involved the total time from the beginning to the end of the reaction. The learner thought that the rate of reaction does not change with time and she thought option D was the correct option. The learner has shown a sign of not understanding what happens with the concentrations of the reactants. But s/he was ultimately happy to realise that as the reaction proceeds, the concentration of the reactants decreases and those of the products increase. This is because as new molecules are formed, the existing molecules experience decrease in quantities, while the new molecules are increasing in quantities.

Question 2

With regard to the effect of heating the reaction vessel, the learner indicated that s/he confused the heat of reaction with the amount of energy required to start the reaction and that when the whole reaction increases, the rate of reaction also increases. The learner showed no understanding of the effect of temperature on the reaction rate because s/he seemed to be mixing up things all together. The learner maintained that

option B is correct because energy is given off. The misconception detected was that the learner confused the reaction rate with the chemical reaction. The reality is that increase in temperature of the reaction vessel increases the reaction rate.

Question 3

When asked how did s/he arrived at option A regarding the effect of temperature on the reaction rate, the learner indicated that s/he looked at only one side of the question and did not consider the temperature on the rate of the reverse reaction. In fact, increase in temperature increases both rates, because as more products are formed they will rapidly decompose to form reactants at the same rate.

Question 4

The learner has got this one correct and has shown full understanding of the concepts.

“verbatim”

“I have learned this from my textbooks that when the temperature of the exothermic reaction is increased the rate of endothermic reaction also increases”.

Question 5

The learner got this question correct and has shown full understanding of the concept tested.

“Verbatim”

“I chose option A, because I knew it from last year that a catalyst does have effect on the reaction rate, it only lowers the activation energy. I thought the question was referring to when the reaction is at equilibrium”.

This learner misunderstood the concepts equilibrium and reaction rate and use them interchangeably as synonyms of each other.

Question 6

The learner was asked to mention the purpose of mixing the reaction vessel as the reaction proceeded and indicated that s/he chose option B because s/he thought if the vessel contents are vigorously mixed then the molecules' kinetic energy would also increase. S/he indicated that though that s/he partially understood the meaning of the question.

Question 7

Regarding the changes which should be done to absolutely increase the reaction rate, the learner indicated that as both reactants are in solid phases, then s/he thought only increase in the surface area would increase the reaction rate. S/he then realised that if one of the reactant's surface area is increased and the other one not, then no reaction rate would be increased for as long as the temperature is not increased. The fact of the matter is that when the temperature of both solid reactants is increased, they will vaporise and their vapours will react to form products.

Question 8

The learner got it correct and had shown full understanding of the importance of activation energy in the chemical reaction and indicated that for atoms of the reactants to mix together, there must be a little amount of energy that allow them to do so. The learner said that s/he knew that the activation energy is a kind of kinetic energy required for reactants to form products. S/he further said:

“verbatim”

“Activation energy is a minimum amount of energy required to form products”

Question 9

The learner got it correct and had shown full understanding of the function of the catalyst in the chemical reaction.

“verbatim”

“The function of a catalyst in a chemical reaction is to lower the activation energy and provide alternative path or mechanism for the reaction”.

Question 10

The learner missed the question all together. The learner has shown that s/he did not fully understand the question and just decided to choose the correct alternative. The question required that s/he choose the wrong statement with regard to the activated complex but surprisingly s/he chose the correct alternative. This was caused by the fact that s/he did not read the question statement to the end.

Learner Ap

Question 1

The learner got this question correct and when s/he was asked how s/he arrived at the correct answer; the learner indicated that s/he knew that because s/he read that from his or her Grade 12 textbook. The learner also indicated that s/he heard that from the teacher during their lessons that reaction rate refers to the colour change of reactants, decrease, or increase in concentration of substances per unit time.

Question 2

When asked about the effect of heating the reaction vessel, the learner indicated that heating provided sufficient kinetic energy of the molecules that enable the molecules to collide with one another. The learner has indicated that s/he has chosen option A, because they were taught that in their class during the lessons. And since then s/he knew that when the reaction vessel is heated the reaction rate increases.

Question 3

With regard to question 3, the learner indicated that s/he thought that increase in temperature only favours the exothermic reaction and has nothing to do with the kinetic

energy of the molecules. The learner said that s/he only thought that the reaction rate for the exothermic reaction would decrease when the reaction vessel is heated.

Question 4

With regard to the endothermic and exothermic reactions, the learner indicated that exothermic reaction occurs independently rapidly, while the endothermic reaction occurs slowly and the two reactions do not form a system. The learner indicated that s/he has chosen option B because s/he thought that increase in the rate of exothermic reaction would not affect the rate of endothermic reaction.

Question 5

The learner got this question correct and when s/he was asked how s/he arrived at the correct alternative; the learner indicated that the function of a catalyst in a reaction is to increase the reaction rate. The learner has shown that s/he has learned about that from the Grade 12 textbook and has also watched a video concerning reaction rate. The learner said that the lecturer on the video lesson explained that the function of the catalyst in the reaction is to increase the reaction rate without itself getting used up.

Question 6

The learner indicated that s/he misunderstood the question and thought that when the reaction mixture is shaken, the kinetic energy of the molecules increases because the particles inside the container are moving. The learner confused shaking the reaction vessel with increase in temperature

4.5 SUMMARY OF CHAPTER

This chapter dealt with representation of data both quantitatively and qualitatively, and analysis of data received from the participants through a questionnaire. The participants were divided into their respective age and gender groups. The next chapter deals with recommendations for further research, teaching, and learning methods that will produce good results and conclusion.

CHAPTER 5

SUMMARY, FINDINGS, AND RECOMMENDATIONS

5.1 INTRODUCTION

In the previous chapter, the focus was on analysing data collected from the participants through questionnaire and interviews. Background information about the participants in term of their age and gender was presented in the form of tables. Pseudonyms were carefully used instead of the real names for both schools and the learners to cover their identities. Teachers qualifications were also looked into just to check the expertise and skills that they have, and inadequacy in terms of provision of good quality education.

This chapter focuses on reviewing the research problem; provide overview and summary of the study, and make recommendations for further research on the problem, as overcoming misconceptions is not an event but a process.

5.2 REVIEW OF THE RESEARCH PROBLEM

The study was carried out to investigate the Grade 12 learners' misconceptions on factors affecting the rate of chemical reactions in some secondary schools in the Capricorn South District. The study showed consistency in the types of misconceptions that learners have in all secondary schools involved in the study. The study also proved that misconceptions really do affect the academic performance of the learners, and deprive them the opportunities to take science as a school subject and pursue their studies in higher institutions of learning. Learners are unable to follow science related careers because their performance in science is poor and fail to obtain minimum marks needed for admission to further their studies. Bidi (2016:5) has shown that the performance of learners in physical science is poor and consistently decline.

5.3 DISCUSSION ON FINDINGS

The following are the aspects of the main findings of the study and are fully discussed below. The aspects are somehow related to the results from the literature review. The aspects identified are:

- a. Construction of knowledge
- b. The learning of reaction rate as a topic
- c. The teaching of reaction rate as a topic
- d. The training of science teachers
- e. Methods of teaching science

5.3.1 The construction of knowledge

The study has shown that learners do not simply come into the learning environment as empty and passive individuals. Learners usually interpret the information they assimilate from their immediate surroundings using previous experiences. Evagorou et al. (2015:4) argued that misconceptions on reaction rate seem to be rooted in the learners' minds long before formal school, and have been problematic towards their progress in chemistry education. The possible sources of these misconceptions are informal learning outside the school, learners' everyday experiences, and the social environment.

The literature further found that learners come into the class with their own conceptions about the natural environment, which are inconsistent with the accepted scientific explanations. These misconceptions cut across gender, age, cultural beliefs, and experiences gained through observations, language, and instructional materials, which are not well structured. It was found that learners in most cases accommodate the newly learned concepts but fail to replace the old incorrect concepts with the new ones.

5.3.2 The learning of reaction rate as a topic

Most literature reported that learners make sense of new information in terms of their prior knowledge based on their past experiences and interaction of the outside environment. These pre-knowledge only makes sense to the learners but do not match the scientifically accepted conceptions. In terms of reaction rate, the study findings showed that some learners in the control group could not differentiate between reaction rate and reaction time. Reaction rate is change in concentration of reactants/products per unit time or change in amount/number of moles/volume/mass of reactants/products per unit time, while reaction time is the time between a stimulus and a response. Research further shown that these views are strongly held in the learners' minds and are persistent to change and make it difficult for learners to learn science conceptions.

Learning is reportedly found to be a social event in which learners should be accorded a conducive learning environment in which they can work together with their peers to allow for their individual differences. Collaboration and discussion influences conceptual change because all learners are actively involved in their groups and share information amongst them. Chemistry contains many concepts which are abstract and hard to grasp, especially if learners are put in a position where they learn without seeing. During the learning process, learners should be encouraged to make an effort and be attentive, and be actively involved in the course of action instead of just being passive recipients of information.

5.3.3 The teaching of reaction rate as a topic

Most of the misconceptions that prevail in learners are resulting from the teachers themselves. Teachers often fail to minimise the difficulties in concept building because they are unable to provide a better perspective related to the basics of chemistry. Reaction rate is a central part of chemistry curriculum, and is important in learning other fundamental chemical concepts. Some research attributed the learners' poor academic performance to the learners' negative attitude to science as a school subject, and learners' poor understanding of the ideas of science.

If there was a correlation between teachers' subject mastery and the learners' academic performance, learners could be doing very well in science. Because of learners' poor performance in science, it means teachers are just teaching without knowing and understanding what they are supposed to be teaching. Good quality teaching would prevail in high achievement by the learners. Karsli and Ayas (2014:664) detected some misconceptions in prospective chemistry teachers. As misconceptions are resistant to change, it is likely that the misconceptions held by those prospective teachers could be passed on to the learners. Teachers and student teachers should have a fully sophisticated subject matter knowledge that will enable them to lessen the occurrence of misconceptions on top of each other.

5.3.4 The training of science teachers

Evagorou et al. (2015:4) showed that research and reform documents have been calling for a total change in the science education curriculum and scientific processes. This is because the science taught in schools today has not changed drastically and it remained the same as some 50 years ago. The traditional goals of science education are out of date and new curriculum need to be developed to replace them. Some of these misconceptions were acquired from secondary education through to universities without being detected. There is a need for university level science education to be structured in such a way that it could reduce and eliminate the misconceptions held by their students in their undergraduate education, and to prevent pre-service teachers from misinforming their learners before they start to practice their profession. Universities should strive to discourage the use of instructional materials and textbooks, which contain inconsistent conceptions in their training of students.

5.3.5 Methods of teaching science

Research showed that teachers play an important role in how learners learn and understand the concepts taught in class. Studies further indicated that teachers reflect their existing knowledge constructions and problem-solving skills on learners. The way learners are taught in classes is a matter of concern, as they are expected to believe without touching or seeing.

The traditional methods of teaching need to be changed and instead laboratory work and computer aided instructions be emphasised or introduced in all schools. The traditional methods deprive learners of the opportunities to explore in details especially in cases where teachers have prior knowledge that mismatch the scientific conceptions. The current technological era depicts that learners can access any information at any given time. So the use of gadgets could really enhance the understanding of any scientific topic under discussion.

5.4 SUMMARY OF FINDINGS

The main findings of this study are summarised below as sub theme A, sub theme B, and sub theme C. The researcher outlines how each of the sub themes was addressed.

5.4.1 Sub theme A: learning of reaction rate as a topic

The study found that only 34.5% of the learners in the experimental group mastered certain concepts, while the majority (65.5%) of the learners struggled to deal with the same concepts in the test (RRCT), and 11 learners out of 20 managed to define reaction rate, whilst 18 learners could not explain the effect of temperature on the reaction rate. This means that most learners do not understand the effect of factors affecting the reaction rate.

The post-test results showed an improvement, as 53% of the learners passed and 47% failed. This showed that learners can only remember what they were just taught and do not accommodate new information in their long term memory. The data gathered in this sub theme assisted the researcher in understanding the difficulties and challenges learners face in their learning processes.

5.4.2 Sub theme B: The teaching of reaction rate as a topic

This research sub theme B assisted in identifying the type of teachers offering science in schools. It was found that one teacher only had a Secondary Teachers' Diploma, which means that he does not have adequate expertise and skills to carry out scientific processes. The other two teachers who were involved in the study deviated from other

professions and join the education fraternity. One of them was employed on a temporary basis, which obviously it affected his work output.

The remaining two teachers were qualified science teachers, although their learners' performance was not on par with their qualifications. The average mark was below five for both the pilot study and the experimental group.

5.5 RECOMMENDATIONS

The following recommendation are made:

- The Education Department must organize intensive content workshops for educators to re-skill and equip them with new teaching techniques and strategies which will help to overcome misconceptions.
- The Education Department must encourage educators to further their studies so that they can explore and acquire new knowledge
- Schools must have functional laboratories or mobile laboratories where learners can perform experiments and not learn by heart.
- Teachers must use computer-aided instructions as they were well prepared to provide relevant information.
- Most learners have language barriers, so Physical science must be taught and written in the language learners understand most.
- Physical science as a subject must be introduced to learners as early as Grade 8 to enable learners to get used to the concepts, and there should be a continuation on the topic throughout the grades with difference in the degree of complexity.

Further studies should be undertaken on reaction rate concept and related topics that precedes this concept so that acceptable scientific knowledge is not built on alternative conceptions. In order to overcome misconceptions, it is necessary that conceptual change strategies are developed that will aim to gradually eliminate the use of concepts not accepted by the science community.

5.6 SUMMARY OF CHAPTER

This study aimed at identifying the misconceptions learners have regarding the factors affecting the reaction rate and related concepts. The focus of the study was to investigate and outline the impact these misconceptions have on the academic performance of the learners; it was found that these misconceptions are resistant to change and teachers should always be vigilant enough to deal with them as soon as they emerge.

5.6.1 Reflection on strength and weakness of the study

5.6.1.1 Strength

The study was a success. The primary aim of examining whether the learners have misconceptions and identifying their sources were achieved.

5.6.1.2 Weakness

As shown earlier in chapter three, only five secondary schools in the whole Capricorn South District were selected for data collection. The same study could be conducted in other districts of the Limpopo province, or other provinces, to generalise the results because misconceptions do exist and they do affect the learning progress of our learners in schools. The research was conducted in a specific region in deep rural area and did not include semi-urban and urban areas of the Province. However, the performance of Physical science in the Province poor compared to other subjects offered in schools which shows that other regions could be having similar or other challenges which contribute towards the problem.

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APPENDICES

ANNEXURE A: DATA COLLECTION TIME-TABLE

SCHOOL CODE	DATE	ACTIVITY	TARGET	DURATION	PERSON RESPONSIBLE
S A	22/09/21	TESTING	ALL GRADE 12 PHYSICAL SCIENCE LEARNERS	2 HRS	MATSEBA MB AND SCIENCE TEACHER
S B	27/09/21	TESTING	ALL GRADE 12 PHYSICAL SCIENCE LEARNERS	2 HRS	MATSEBA MB AND SCIENCE TEACHER
S C	28/09/21	TESTING	ALL GRADE 12 PHYSICAL SCIENCE LEARNERS	2 HRS	MATSEBA MB AND SCIENCE TEACHER
S D	29/09/21	TESTING	ALL GRADE 12 PHYSICAL SCIENCE LEARNERS	2 HRS	MATSEBA MB AND SCIENCE TEACHER
S E	30/09/21	PRE- AND POST-TESTING	ALL GRADE 12 PHYSICAL SCIENCE LEARNERS	2 HRS	MATSEBA MB AND SCIENCE TEACHER
S C	12/10/21	INTERVIEWS	4 LEARNERS DOING SCIENCE	1HR	MATSEBA MB
S E	13/10/21	INTERVIEWS	4 LEARNERS DOING SCIENCE	1HR	MATSEBA MB
S A	14/10/21	INTERVIEWS	4 LEARNERS DOING SCIENCE	1HR	MATSEBA MB
S D	18/10/21	INTERVIEWS	4 LEARNERS DOING SCIENCE	1HR	MATSEBA MB
S B	19/10/21	INTERVIEWS	4 LEARNERS DOING SCIENCE	1HR	MATSEBA MB

ANNEXURE B: GENERAL INFORMATION FORM: PARTICIPANTS



GRADE 12 LEARNERS' MISCONCEPTIONS ABOUT FACTORS AFFECTING THE RATE OF CHEMICAL REACTION

Information Sheet

Dear Participant,

My name is Matseba Marome Bester and I am a student, doing Master`s dissertation in the Department of humanities at Central University o technology (CUT) You are invited to participate in a research study about factors that affect the rate of reaction. You were selected as a possible participant because you form part of Lepelle 2 circuit so what happens to other learners in this area affects you also directly or indirectly. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 17 or older to participate in the study. The purpose of this form is to inform you about the study.

Why am I being invited to take part in this study?

You are invited to take part in this study because you form part of Lepelle 2 circuit so what happens to other learners in this area affects you also directly or indirectly. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 17 or older to participate in the study. The purpose of this form is to inform you about the study.

What will I do if I agree to participate?

If you agree to participate in the study, you will

- Write a pre-test for an hour during the first day of the study.
- Be prepared to be taught about factors affecting reaction rate and related concepts.
- Write a post-test immediately after been taught about reaction rate.
- Participate in the interviews that will follow after marking the post test.

What happens if I say yes, but I change my mind later?

Your participation in this study is voluntary. You may decline to participate at any time, even after the study has started. If you choose not to participate or to withdraw from the

study, there will be no penalty, and you will be able to keep any incentives you have earned up to the point at which you withdraw.

What are the benefits to me for being in this study?

There are no direct benefits to participation in this study, however, your participation will help in developing the curriculum and designing proper teaching methodologies to make the subject content more understandable to learners. This study will expose you to different styles of questioning that will stimulate your interests in the subject and will also help in eliminating some misconceptions pertaining to the topic.

What happens to the information collected for the study?

Your responses or any other information will be anonymous or handled with strictly high confidentiality. Pseudonyms will be used instead of real school names and learners' names. No information that may leak during study will be found pointing directly at certain individuals.

The results of this study may be used in reports, presentations, or publications but your name or your school name will not be used. No individual marks will be recorded. The study results will be shared in aggregate form not pointing at a particular school or individuals. The data on the hard copies will be kept safe in the University's store room for a period of three years and all software copies will be stored in password protected computers accessed only by the researcher and the supervisor. After three years the digital files will be erased and all hard copies will be shredded.

Is there any way being in this study could be bad for me? Is there any risk to me by being in this study? If so, how will these risks be minimised?

There are minimal risks and inconveniences to participating in this study. These include:

- Losing quality study time engaging in the research study.
- Participants may be uncomfortable answering the survey or interview questions.
- A risk might be a possible loss of confidentiality where other participants' responses can be seen by other participants.

Who should I contact for questions?

If you have questions about the study, please call me at 082 746 4659 or e-mail me at matsebabester@gmail.com. If you have any questions about your rights as a participant in this research or if you feel you have been placed at risk, you can contact my supervisor at 082 338 9259.

PLEASE KEEP THIS INFORMATION SHEET FOR YOUR RECORDS

Adapted from: <https://www.csusm.edu/gsr/irb/consent.html>

ANNEXURE C: GENERAL INFORMATION FORM COVID-19



GRADE 12 LEARNERS' MISCONCEPTIONS ABOUT FACTORS AFFECTING THE RATE OF CHEMICAL REACTION.

Informed Consent Covid-19 compliant

Dear Learners and Principal

My name is Matseba Marome Bester and I am a student, doing Master`s dissertation in the Department of Humanities at Central University of technology (CUT). You are invited to participate in a research study about factors that affect the rate of reaction. You are selected as a possible participant because you form part of Lepelle 2 circuit. So what happens to other learners in this circuit affects you also directly or indirectly. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 18 or older to participate in the study.

KEY INFORMATION ABOUT THIS RESEARCH STUDY:

The following is a short summary of this study to help you decide whether to be a part of this study. Information that is more detailed is listed later on this form.

The purpose of this study is to examine the high school learners' misconceptions and views with regard to reaction rate. You will be asked to write both Pre-test and Post-test consisting of ten multiple choice questions regarding reaction rate followed by a short interview that is aimed at checking your understanding and views concerning the topic. We expect that you will be in this research study for 1 hour per week until we are done with the interviews with some of the learners who will be randomly selected. There is no risk in participating in this study because your responses will be dealt with at high confidentiality and you will be using pseudonyms instead of your real names. There is no benefit in participating in this study, except that you will be exposed to different types of questions which might arouse your interest in studying further and that your views might be considered when developing curriculum in future.

STUDY PURPOSE:

- Determine how misconceptions develop in learners' memories.
- Identify learners` alternative concepts with regard to reaction rate.
- Develop strategies to overcome identified alternative conceptions.

- Determine the extent to which these misconceptions affect the learners' learning of reaction rates.

NUMBER OF PARTICIPANTS:

Sebitja Secondary School	Experimental Group	20
Phalakgoro-Mothoa High School	Control Group	18
Makgwading High School	Control Group	20
Serutle Secondary School	Control Group	16
Mampotjane High School	Control Group	18

PROCEDURES FOR THE STUDY:

- Write a pre-test for an hour during the first day of the study.
- Be prepared to be taught about factors affecting reaction rate and related concepts.
- Write a post-test immediately after been taught about reaction rate.
- Participate in the interviews that will follow after marking the post test.

RISKS AND INCONVENIENCES:

There are risks and inconveniences to participating in this study. These include:

- Losing quality study time engaging in the research study.
- Participants may be uncomfortable answering the survey or interview questions.
- A risk might be a possible loss of confidentiality where other participants' responses can be seen by other participants.
- If you are anxious or fearful of being exposed to COVID-19 in this study, take note that all participants will observe covid-19 protocols, thus, observe social distancing, wear a cloth mask and sanitise regularly.
- To limit chances of contracting COVID-19 your desks will be sanitised before and after sitting on them. You will be sanitised before and after receiving the questionnaire.

SAFEGUARDS:

To minimise these risks and inconveniences, the following measures will be taken:

- The study will be undertaken within the time allocated for study.
- No classes will be disrupted as learners will be engaged in self-study.
- Participants can skip any questions that they feel uncomfortable in answering it.
- Participant may skip any part of the interventions suggested by the researcher. If you are anxious or fearful of being exposed to COVID-19 in this study, take note

that all participants will observe covid-19 protocols, thus, observe social distancing, wear, a cloth mask and sanitise regularly.

- To limit chances of contracting COVID-19 your desks will be sanitised before and after sitting on them. You will be sanitised before and after receiving the questionnaire.

CONFIDENTIALITY:

Your responses or any other information will be anonymous or handled with strictly high confidentiality. Pseudonyms will be used instead of real school names and learners' names. No information that may leak during study will be found pointing directly at certain individuals.

The results of this study may be used in reports, presentations, or publications but your name or your school name will not be used. No individual marks will be recorded. The study results will be shared in aggregate form not pointing at a particular school or individuals. The data on the hard copies will be kept safe in the University's store room for a period of three years and all software copies will be stored in password protected computers accessed only by the researcher and the supervisor. After three years the digital files will be erased and all hard copies will be shredded.

VOLUNTARY PARTICIPATION:

Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty. Your decision whether or not to participate in this study will not affect your current or future relations with the school.

BENEFITS OF TAKING PART IN THE STUDY:

There are no direct benefits to participation in this study, however, your participation will help in developing the curriculum and designing proper teaching methodologies to make the subject content more understandable to learners. This study will expose you to different styles of questioning that will stimulate your interests in the subject and will also help in eliminating some misconceptions pertaining to the topic.

ALTERNATIVES TO TAKING PART IN THE STUDY:

The study will be executed during after school hours (during study period). If you decide not to participate in this study, you have the option to go in another classroom and study as per your study time-table.

PAYMENT OR INCENTIVE:

You will not receive any sort of payment for taking part in this study. Participation is voluntary and participants can decline anytime if they so wish.

STUDY-RELATED INJURIES:

So far as the researcher is concerned, the study is of lower risk as no injuries or harm can be incurred during the writing of the test.

CONTACT INFORMATION:

If you have questions about the study, please call me at 082 746 4659 or e-mail me at matsebabester@gmail.com. Or contact my supervisor at 082 338 9259. You will be given a copy of this form for your records. If you have any questions about your rights as a participant in this research or if you feel you have been placed at risk, you can contact the Education Department or the Central University of technology for clarity.

PARTICIPANT'S CONSENT:

By signing below, you are giving consent to participate in the study. You will be audio taped so that we can have original ideas or views of the participants for future references. Please tick the option that applies to you before signing with the following options:

- I give permission for my interviews to be audio or video taped.
- I do not give permission for my interviews to be audio or video taped.
- I have been informed about the risk of exposure to COVID-19 in this study. I understand that regardless of any precautions taken, a possible risk of exposure to the virus still exists.

Name of the Participant: _____

Signature of the Participant: _____

Date: _____

Adapted from: <https://www.csusm.edu/gsr/irb/consent.html>

ANNEXURE D: INFORMED CONSENT



GRADE 12 LEARNERS' MISCONCEPTIONS ABOUT FACTORS AFFECTING THE RATE OF CHEMICAL REACTION

Informed Consent

INVITATION TO PARTICIPATE:

Dear LEARNER

My name is Matseba Marome Bester and I am a student, doing Master`s dissertation in the Department of humanities at Central University o technology (CUT) You are invited to participate in a research study about factors that affect the rate of reaction. You were selected as a possible participant because you form part of Lepelle 2 circuit so what happens to other learners in this area affects you also directly or indirectly. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 18 or older to participate in the study.

KEY INFORMATION ABOUT THIS RESEARCH STUDY:

The following is a short summary of this study to help you decide whether to be a part of this study. Information that is more detailed is listed later on in this form.

The purpose of this study is is to examine the high school learners' misconceptions and views with regard to reaction rate. You will be asked to write both Pre-test and post-test consisting of ten multiple choice questions regarding reaction rate followed by a short interview that is aimed at checking your understanding and views concerning the topic We expect that you will be in this research study for four hours per month until we are done with the interviews with some of you whom will be randomly selected. There is no risk in participating in this study because your responses will be dealt with at high confidentiality and you will be using pseudonyms instead of your real names. There is no benefit in participating in this study, except that you will be exposed to different types of questions which might arouse your interest in studying further and that your views might be considered when developing curriculum in future.

STUDY PURPOSE:

The purpose of this study is to:

- Determine how misconceptions develop in learners' memories.
- Identify learners `alternative concepts with regard to reaction rate.

- Develop strategies to overcome identified alternative conceptions.
- Determine the extent to which these misconceptions affect the learners' learning of reaction rates.

NUMBER OF PARTICIPANTS:

If you agree to participate, you will be one of 92 participants in this study.

Sebitja Secondary School	Experimental Group	20
Phalakgoro-Mothoa High School	Control Group	18
Makgwading High School	Control Group	20
Serutle Secondary School	Control Group	16
Mamopotjane High School	Control Group	18

PROCEDURES FOR THE STUDY:

If you agree to be in the study, you will do the following:

- Write a pre-test for an hour during the first day of the study.
- Be prepared to be taught about factors affecting reaction rate and related concepts.
- Write a post-test immediately after been taught about reaction rate.
- Participate in the interviews that will follow after marking the post test.

RISKS AND INCONVENIENCES:

There are risks and inconveniences to participating in this study. These include:

- Losing quality study time engaging in the research study.
- Participants may be uncomfortable answering the survey or interview questions.
- A risk might be a possible loss of confidentiality where other participants' responses can be seen by other participants.

SAFEGUARDS:

To minimise inconveniences, the following measures will be taken:

- The study will be undertaken within the time allocated for study.
- No classes will be disrupted as learners will be engaged in self-study.
- Participants can skip any questions that they feel uncomfortable in answering it.
- Participant may skip any part of the interventions suggested by the researcher.

CONFIDENTIALITY:

Your responses or any other information will be anonymous or handled with strictly high confidentiality. Pseudonyms will be used instead of real school names and learners'

names. No information that may leak during study will be found pointing directly at certain individuals.

The results of this study may be used in reports, presentations, or publications but your name or your school name will not be used. No individual marks will be recorded. The study results will be shared in aggregate form not pointing at a particular school or individuals. The data on the hard copies will be kept safe in the University's store room for a period of three years and all software copies will be stored in password protected computers accessed only by the researcher and the supervisor. After three years the digital files will be erased and all hard copies will be shredded.

VOLUNTARY PARTICIPATION:

Participation in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty. Your decision whether or not to participate in this study will not affect your current or future relations with the school.

BENEFITS OF TAKING PART IN THE STUDY:

There are no direct benefits to participation in this study, however, your participation will help in developing the curriculum and designing proper teaching methodologies to make the subject content more understandable to learners. This study will expose you to different styles of questioning that will stimulate your interests in the subject and will also help in eliminating some misconceptions pertaining to the topic.

PAYMENT OR INCENTIVE:

You will not receive any sort of payment for taking part in this study. Participation is voluntary and participants can decline anytime if they so wish.

ALTERNATIVES TO TAKING PART IN THE STUDY:

The study will be executed during after school hours (during study period). If you decide not to participate in this study, you have the option to go in another classroom and study as per your study time-table.

STUDY RELATED INJURIES:

So far as the researcher is concerned, the study is of lower risk as no injuries or harm can be incurred during the writing of the test.

CONTACT INFORMATION:

If you have questions about the study, please call me at 082 746 4659 or e-mail me at matsebabester@gmail.com. Or contact my supervisor at 082 338 9259. You will be given a copy of this form for your records. If you have any questions about your rights as a participant in this research or if you feel you have been placed at risk, you can contact the Education Department or the Central University of technology for clarity.

PARTICIPANT'S CONSENT:

By signing below, you are giving consent to participate in the study. You will be audio taped so that we can have original ideas or views of the participants for future

references. Please tick the option that applies to you before signing with the following options:

- I give permission for my interview to be audio or video taped.
- I do not give permission for my interview to be audio or video taped.

Name of the Participant: _____

Signature of the Participant: _____

Date: _____

Adapted from <https://www.csusm.edu/gsr/irb/consent.html>

ANNEXURE E: GENERAL PARENTAL CONSENT FORM



GRADE 12 LEARNERS' MISCONCEPTIONS ABOUT FACTORS AFFECTING THE RATE OF CHEMICAL REACTION

Parental Consent

INVITATION TO PARTICIPATE:

Dear Parent/ Guardian

My name is Marome Bester Matseba and I am a student in the Department of humanities at Central university of Technology (CUT). I am conducting a research study to examine the high school learners' misconceptions and views with regard to reaction rate. The purpose of this form is to provide you with information that will help you decide if you will give consent for your child to participate in this research.

KEY INFORMATION ABOUT THIS RESEARCH STUDY:

The following is a short summary of this study to help you decide whether you want your child to be a part of this study. Information that is more detailed is listed later on in this form.

The purpose of this study is to examine the high school learners' misconceptions and views with regard to reaction rate. Your child will be asked to write a Pre- and Post-tests during the study periods on week days followed by an interview aiming at better understanding the learners' ideas and views concerning reaction rate. We expect that your child will be in this research study for four hours per month until we are done with the interviews with some of you whom will be randomly selected. There is no risk in participating in this study because your responses will be dealt with at high confidentiality and you will be using pseudonyms instead of your real names. There is no benefit in participating in this study, except that you will be exposed to different types of questions which might arouse your interest in studying further and that your views might be considered when developing curriculum in future.

STUDY PURPOSE:

The purpose of this study is to:

- Determine how misconceptions develop in learners' memories.
- Identify learners' alternative concepts with regard to reaction rate.
- Develop strategies to overcome identified alternative conceptions.

- Determine the extent to which these misconceptions affect the learners' learning of reaction rates.

NUMBER OF PARTICIPANTS:

Sebitja Secondary School	Experimental Group	20
Phalakgoro-Mothoa High School	Control Group	18
Makgwading High School	Control Group	20
Serutle Secondary School	Control Group	16
Mampotjane High School	Control Group	18

PROCEDURES FOR THE STUDY:

If you agree for your child to participate in the study, she or he will:

- Write a pre-test for an hour during the first day of the study.
- Be prepared to be taught about factors affecting reaction rate and related concepts.
- Write a post-test immediately after been taught about reaction rate.
- Participate in the interviews that will follow after marking the post test.

RISKS AND INCONVENIENCES:

There are minimal risks and inconveniences to participating in this study. These include:

- Losing quality study time engaging in the research study.
- Participants may be uncomfortable answering the survey or interview questions.
- A risk might be a possible loss of confidentiality where other participants' responses can be seen by other participants.

SAFEGUARDS:

To minimise these risks and inconveniences, the following measures will be taken:

- The study will be undertaken within the time allocated for study.
- No classes will be disrupted as learners will be engaged in self-study.
- Participants can skip any questions that they feel uncomfortable in answering it.
- Participant may skip any part of the interventions suggested by the researcher.

CONFIDENTIALITY:

Your child's responses or any other information will be anonymous or handled with strictly high confidentiality. Pseudonyms will be used instead of real school names and learners' names. No information that may leak during study will be found pointing directly at certain individuals.

The results of this study may be used in reports, presentations, or publications but your name or your school name will not be used. No individual marks will be recorded. The study results will be shared in aggregate form not pointing at a particular school or individuals. The data on the hard copies will be kept safe in the University's store room for a period of three years and all software copies will be stored in password protected computers accessed only by the researcher and the supervisor. After three years the digital files will be erased and all hard copies will be shredded.

VOLUNTARY PARTICIPATION:

Your child's participation in this study is voluntary. Your child may decline participation at any time. You may also withdraw your child from the study at any time; there will be no penalty. Likewise, if your child chooses not to participate or to withdraw from the study at any time, there will be no penalty.

BENEFITS OF TAKING PART IN THE STUDY:

There are no direct benefits of your child's participation in this study, however, your child's participation will help in developing the curriculum and designing proper teaching methodologies to make the subject content more understandable to learners. This study will expose you to different styles of questioning that will stimulate your child's interests in the subject and will also help in eliminating some misconceptions pertaining to the topic.

PAYMENT OR INCENTIVE:

You will not receive any sort of payment for taking part in this study. Participation is voluntary and participants can decline anytime if they so wish.

ALTERNATIVES TO TAKING PART IN THE STUDY:

The study will be executed during after school hours (during study period). If you do not give consent to your child to participate in this study, your child will have the option of going in another classroom and study as per his/her study time-table.

CONTACT INFORMATION:

If you have questions about the study, please call me at 082 746 4659 or e-mail me at matsebabester@gmail.com. Or contact my supervisor at 082 338 9259. You will be given a copy of this form for your records. If you have any questions about your rights as a participant in this research or if you feel you have been placed at risk, you can contact the Education Department or the Central University of technology for clarity.

PARENT'S CONSENT:

By signing below, you are giving consent for your child to participate in the above study. You will be audio taped so that we can have original ideas or views of the participants for future references. Please tick the option that applies to you before signing with the following options:

- I give permission for my child to be audio/video taped.
- I do not give permission for my child to be audio/videotaped.

Your child's name: _____

Parent's name: _____

Parent's Signature: _____

Date: _____

Adapted from <https://www.csusm.edu/gsr/irb/consent.html>

ANNEXURE F: RESEARCH ETHICAL APPROVAL (ETHICAL CLEARANCE)



RESEARCH ETHICS APPROVAL

Date: 2 September 2021

This is to confirm that ethical clearance has been provided by the Faculty Research and Innovation Committee [01/06/16] in view of the CUT Research Ethics and Integrity Framework, 2016.

Ethical clearance number:

HREIC 05/20/07 ST.M.Ed

Applicant's Name and student number	Matseba MR 220049953
Supervisor's Name for Student Project	Prof P Sepeng Dr ET Ngobeni
Level of Qualification for Student's Project	M.Ed
Title of research project	Grade 12 learners' misconceptions about factors that affect the rate of chemical reaction
FRIC approval number	FRIC 05/20/07

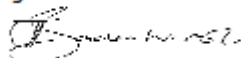
All conditions as set out below have to be met as set out in your LS 262 a form.

As this research focuses primarily on human beings you will be ethically responsible for:

- protecting the rights and welfare of the participants;
- gaining the trust and co-operation of all the participants with the assurance that the information collected will be kept confidential;
- informing the participants from the outset that their participation will be voluntary, and that the data collected will be conducted with the consent of the relevant Department of Education, the director of the relevant District, the principal(s) of the sample school(s), the teachers, and the learners;
- adhere to the principles of rigorous data collection, analysis and interpretation consistent with the design of the study;
- keeping a data trail for possible auditing purposes and safe-keeping of raw data for a period of three years after publication of the results/findings;
- respecting the confidentiality of the data.

We wish you success with your research project.

Regards



Prof JW Badenhorst
(Chairperson: Faculty of Humanities Research Ethics and Integrity Committee)

ANNEXURE G: PERMISSION LETTER FROM PROVINCIAL EDUCATION DEPARTMENT

**DEPARTMENT OF
EDUCATION**

Ref: 2/2/2 Enquiries: Makola MC Tel No: 015 290 9448 E-mail: MakolaMC@edu.limpopo.gov.za

Matseba MB
P.O Box 1498
Lebowakgomo
0737

RE: REQUEST TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal reads as follows: **“Grade 12 learners’ misconceptions regarding factors affecting reaction rate”**.
3. The following conditions should be considered:
 - 3.1 The research should not have any financial implications for Limpopo Department of Education.
 - 3.2 Arrangements should be made with the Circuit Office and the School concerned
 - 3.3 The conduct of research should not in any how disrupt the academic programmes at the school(s)
 - 3.4 The research should not be conducted during the time of Examinations especially in the fourth term
 - 3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected and treated with dignity)

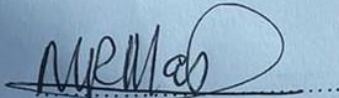
r. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE
Tel: 015 290 7600, Fax: 015 297 6920/4220/4494

The heartland of southern Africa - development is about people!

3.6 Upon completion of the research, the researcher shall share the final product of the research with the Department.

- 4 Additionally, you are expected to produce this letter at School(s)/Office(s) where you intend to conduct your research as an evidence that permission has been granted for access to the research site(s).
- 5 The Department appreciates the contribution that you wish to make and wishes you success in your investigation

Best wishes



Mashaba KM

DDG: Corporate Management

10/01/2022

Date

ANNEXURE H: EDITING LETTER

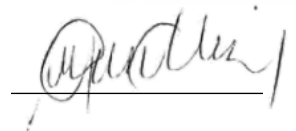


Marieta Grundling (MBA)

366 Rosemary Street
Grootfontein Country Estates
Pretoria, 0081
081 354 1596
edit@profeditmba.co.za
9 January 2023

To Whom It May Concern

This serves to confirm that the dissertation: *Grade 12 learners' misconceptions about factors which affect the rate of reaction: An investigation in some secondary schools around Capricorn South district in Limpopo* by **Matseba Marome Bester** was edited. The language, presentation, referencing system (both in-text and against the Reference List), were checked and corrected.



M Grundling

9 January 2023