Exploring the ICT integration in chemistry practical work

Submitted by

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Abstract

Over the years, the diagnostic report on the physical science matric results has indicated that the inability of learners to perform well in the Chemistry section came from the section of Rates of reactions as well as Chemical equilibrium. The challenges with the topic is the inability of learners to represent and interpret experimental data on the graphs. Literature shows that learners have an iconic misconception about graphs, as they view graphs as images and not scientific representation of relationship between variables. The challenge of learners indicate that they do not understand the concept well enough to make a relationship between an experiment and how the results of an experiment can be represented graphically. This implies that teachers may also be having the same challenge and could mean that pre-service teachers are unable to comprehend the relationship between experimental findings from the Rates of reactions and Chemical equilibrium.

This study sampled five (5) physical science pre-service teachers and one (1) teacher educator in the fourth year to collect data that provided some insight on factors that affect understanding of the link between practical aspects and interpretation of experimental data from these topics. Since data was collected during the lockdown due to the COVID19 pandemic, data was collected online when ICT resources were used for teaching and learning. This study explored how the integration of ICT incorporated in the teaching and assessment of practical tasks can affect preservice teacher's ability to interpret graphs on these topics. The PCK theoretical framework was chosen for this study aimed at examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge and content knowledge complex interplay. Qualitative data was collected through online classroom observations, interviews and document analysis. During lesson observations the teacher educator delivered a lesson on rates of reactions and chemical equilibrium using videos. Interviews were conducted with both teacher educators and students to understand the usefulness of ICT integration in chemistry practical. Document analysed were practical booklets used by students to respond to questions on a practical task. These were used to examine students' practical work with purpose of tracking the adequacy of ICT integration in chemistry practical work particularly to the graphical interpretation related question.

The TPACK interplay allowed the study to understand if content taught links with pedagogy applied (practical work) and how these two are empowered by ICT, accordingly, determining the usefulness of ICT integration in students' graphical interpretations". Teachers became aware of the interplay of technological knowledge, pedagogical knowledge, and content knowledge which enabled them to strategically use graphs as concepts were explained thereby improve in their understanding and interpretation of graphs. During interviews, preservice teachers admitted that the use of ICT provided a clear visual with clear readings, making it for them to identify independent, dependent variables and to analyse, compare, describe, interpret graphs. However, the minority claim conceptual understanding is rather a more crucial point toward understand and identifying. This study concludes that ICT is useful in graphical interpretation provided that teacher educators show awareness of TPACK, strategically exposing students to graphical related content. Revisiting basics for graphical related concepts is important as conceptual understanding is directly linked to graphical interpretation.

Key words: ICT integration, Chemistry, Rates of reactions, Chemical equilibrium. Graph interpretation

DECLARATION

I Thulebona Mzileni (1444359) declares that the research project is my own work. It was never submitted before on other university for any examination or degree. All the work used in this study was taken directly from the other works that has been cited appropriately and a full reference list has been provided. I fully comprehend that the University of the Witwatersrand will take disciplinary action against me if evidence suggest that this is not my own unaided work or if I failed to acknowledge Ideas in my writing.

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Students signature: 

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List of acronyms used in this study:

AT	Activity Theory
CK	Content knowledge
DBE	Department of Basic Education
ICT	Information communication technology
MBL	Micro-computer Based Laboratory
PCK	Pedagogical content knowledge
PK	Pedagogical Knowledge
TCK	Technological Content Knowledge
TK	Technological Knowledge
TPACK	Technological pedagogical content knowledge
TPK	Technological pedagogical Knowledge

List of tables

List of figures

Contents

Chapter 1

CHAPTER 1: INTRODUCTION AND OVERVIEW OF THE STUDY

1.1 Introduction

Information communication technology (ICT) has a potential to reinforce education and avail opportunities across the curriculum for effective communications between teachers and students (Dawes, 2001). ICT is a term that emphasise the use, integration of telecommunications, software, computers, and audio-visual systems to enable users to create, store, access, manipulate and transmit information (Dori, Rodrigues & Schanze, 2013). The 21st century has brought about a growth in a use of ICT, and an increase in data presentation using visuals in the form of tables and graph of different kinds in daily life activities (Glazer, 2011). Making sense of data from visual representations is an essential skill required in the current information age (Glazer, 2011). He adds that it is thus imperative to be computer and scientifically literate in this century, as these competencies are considered crucial for employment in this century.

Drawing out of latent talent, skills, and realization of self-potential of an individual can be complemented and alleviated through a use of ICT (Ibieta, Hinostroza, Labbe & Claro, 2017). Henderson (2020) argue that ICT benefits have been shown to make the educative process interesting and adds that this contributes to student's willingness to learn, which enables them to learn better out of interest and curiosity. It improves teacher-learner interaction as well in the teaching and learning process (Kler, 2014). Improved learning conditions through the use of ICT means a teacher must be aware of the challenges that comes with integration of ICT in education such as a lack of infrastructure in institutions, lack of teacher confidence, teacher competence, learner's accessibility due to internet related issues, lack of effective training and resistance to change (Bingimlas, 2009). These factors may influence teacher's resistance to change from traditional teaching methods.

The lockdown due to the COVID-19 pandemic forced institutions to make a transition from contact to online learning programmes (Sahu, 2020). This study acknowledges that the transition from traditional face-to-face learning to the inclusion of ICT in teaching and learning is not a new initiative in South African learning institutions but was rather accelerated by the lockdown due to the COVID-19 pandemic. Countries such as United States, Singapore and Australia have been adopting blended learning, which integrates the online learning practices into face-to-face learning to meet learners needs (Watson, 2008). The transition is not only to blended learning as some higher institutions are transitioning to fully online courses adopting the use of technology to accommodate learners' needs (Keengwe & Kidd, 2010).

ICT can frequently engage learners, allowing them to provide solutions in the educative process. Moreover, through successful engagement it is easier for learners to have meaningful understanding of concepts taught (Fu, 2013). Implementation of ICT enhances learning, it links different traditional educational technologies such as writing, books, databases, games, television and more to facilitate learning (Livingstone, 2012). In a science classroom the ICT affordances is that tasks conducted through this mode of learning can extend learning beyond the classroom or class contact time and does not rely on a use of laboratory or specific classroom (Denby & Holman, 2002). Exploring the issue of practical work, ICT such as spreadsheets, computer-based lab, simulation software's can offer an advantage of quality data which can include more accurate experimental readings and allows repetitive tasks to be carried out quickly (Denby & Holmam, 2002). Video-practical work may perform the similar tasks if data loggers are used (Rodrigues, Pearce & Livett, 2001). The contact-online transition has impact on how teaching and learning occurs, as the teachers must abandon the traditional way of teaching to using online learning as the mode of learning (Sahu, 2020).

1.2 Theoretical Framework

The study's theoretical framework is Pedagogical content knowledge (PCK) which originates from Shulmans work (1986). Arising from this theoretical framework is the Technological Pedagogical content knowledge (TPACK) which is a conceptual framework that acts as lenses of this study to understand the ICT integration in chemistry practical work (Swallow & Olofson, 2017). TPACK considers the role of technology in teaching, and this align with the study since it explores the ICT use in chemistry practical work with a purpose of understanding the ongoing conundrum of poor performance in physical sciences. Lower achievement in this subject is linked to poor graph interpretations due to lack of exposure to practical work and as a result learners' majority of learners score below 50% average in this subject (DBE, 2021). Interpreting graphs images well is possible if prowess in graphing skills is possessed by learners (Gultepe, 2016). Graphing skills can be attained through practical work which ICT integration practical proves to be useful in showing chemistry microscopic, symbolic, macroscopic thus improving learners understanding of chemistry concepts explored through ICT integrated practical work (Pernaa & Aksela, 2009). Understanding the issue of poor graphical interpretation, the study will explore how practical work that is ICT integrated may be useful. This will be done through document analysis relying on activity theory which builds on Vygotsky's work to conceptualise learning to analyse 4th year student's practical work (Isssroff & Scanlon, 2002). Document analysis conducted by a way of examining students practical work with purpose of tracking the adequacy of ICT integration in chemistry practical work particularly to the graphical interpretation related question. Further, interviews will be conducted with both teacher educators and students to understand the usefulness of ICT integration in chemistry practical.

1.3 Background

The South African school report on the poor performance in physical science in matric for the past years has been associated with lack of exposure to laboratory work for learners to attain practical skills including the concepts of chemistry (DBE, 2020). Assessment of laboratory skills includes representing experimental results in graphs and interpreting graphs that shoe experimental results. Gultepe (2016), reflected on high school students' graphing skills and their conceptual understanding of drawing chemistry graphs, and discovered that learners can improve their graphing skills in science and chemistry. Glazer (2011) indicated that over the years, undergraduate students have encountered difficulties in interpreting graphs in chemistry. Graphs in chemistry are useful in providing alternatives to algorithmic and verbal descriptions through offering learners with a different route central to improving learner's manipulation of concepts (Gultepe, 2016). He adds that manipulation of concepts in chemistry means teachers should be knowledgeable and be aware of students graphing skills, as learners are known to have trouble in finding links between the chemistry concepts, real world, and the graphs of different variables. DBE concurs that practical work requires more attention to ensure learners can apply practical skills and knowledge such as identifying variables, interpretation data, drawing conclusions and drawing graphs (DBE, 2021). The attainment of practical skills is possible through following a scientific experiment in a laboratory through contact session (Woodley, 2009).

The topics of Rates of reactions and Chemical equilibrium which are examinable in grade 12 examinations, have practical components whose assessment include representing and interpretation of graphs. After perpetual challenges on the questions based on experimental data, the 2020 diagnostic report still indicated the following challenges that were observed in the matric students responses: Candidates could not identify the dependent and the independent variables correctly, Most candidates did not know that the gradient of the graph represented reaction rate In many candidates interpreted the graph parallel to the x axis as representing a reaction that reached equilibrium. They did not know that the gradient of the graph represented reaction rate, candidates did not interpret the graph correctly and therefore did not know that the reaction time, Many candidates failed to interpret the table (containing data) to conclude that the reaction will take place at a faster rate .The report suggested that Practical skills should receive more attention in schools as learners have a poor understanding of skills such as identifying variables and interpreting graphs (DBE,2020). Whereas the DBE reports mention challenges affecting learners in grade 12 level, these learners progress with the same challenges tertiary institutions. Pre-service teachers' graphing skills have been explored by studies such as Bowen & Roth (2005), data and graph interpretation practices among preservice science teachers and Kilic, Sezen & Sari (2012).

Online learning does not use contact sessions or physical science laboratory but rather ICT. The use of ICT such as computer simulations, videos and modelling can offer the practical skills to students and help them with reaching a sound understanding of scientific phenomena and concepts taught (Woodley, 2009). Experimental tasks may involve inscriptions. The term inscription is used to discern the external representations such as tables and graphs in material form from internal representation that is often used by psychologists to describe mental structures (Glazer, 2011). Bowen & Roth, (2005) argue that inscriptions are useful in representing a physical phenomenon, representations such as tables, maps, lists, equations, and graphs. They also refer to external or visual representations and are essential in the science practices as they can be transformed, labelled, and superposed, and can be incorporated in writing. Furthermore, they support scientific claims made convincingly. Graph representation is a common method to illustrate the relationships between variables visually in the data (Slutsky, 2014). These variables are the dependent, independent, and controlled variables. David & Slutsky (2014) posits that graphs present a great deal of data that is complicated to be reported satisfactory in the text and in less space. Theretofore the study focuses on the exploration of content focusing on how relationships of the rate of reactions and chemical equilibrium are taught by examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge and content knowledge complex interplay. The TPACK interplay allowed the study to understand if content taught links with pedagogy applied (practical work) and how these two are empowered by ICT, accordingly, determining the usefulness of ICT integration in students' graphical interpretations.

1.4 Problem Statement

Graphs serve as essential material in science education to improve students understanding of the relationships and scientific concepts including chemistry concepts, summarizing the subject matter, and constructing conceptual framework (Kilic, Sezen & Sari, 2012). Students understanding and interpretation of relationship between scientific concepts is linked to their successful interpretation and comprehension of graphs (Secken & Yoruk, 2012). Facilitation of conceptual understanding is essential in assisting learners to make sense of graph representations as graphing skills are central to students for exploiting the knowledge and potential offered by reading graphs (Tesla, Monroy & Sassi, 2002). Undergraduates' students are having trouble in graph interpretations for chemistry due to inadequate graphing skills and in turn, students fail to benefit from the potential offered by reading graphs (Kilic, Sezeni & Sari, 2012). Students' difficulties in graph interpretations depict that student fail to find links between graphs, real world and a physical concept. Moreover, they have shown to be unsuccessful in integrating conceptual information and visual representation, as they perceive graphs as pictures without considering their abstract nature (Aydin, 2007).

At the undergraduate level, both non-science and science students have experienced difficulties in variables identification, interpretation of variable relationship, detection of data trends, and ability to transform simple data into graphical forms indicating a lack of graphing skills (Harsh & Schmitt-Harsh, 2016). Student's inability to interpret graphs as part of chemistry teaching, representing scientific phenomenon relies on the coordination of representational levels including symbolic representations such as equations, analogies, reaction mechanisms and graphs (Santos & Arroio, 2016). Graphing skills can be obtained through students' active participation in authentic scientific investigations of contextualised and realistic problems such as practical work as it offers practical skills (Harsh & Schmitt-Harsh, 2016). Inadequate graphing skills and poor graph interpretations is linked to lack of practical skills and exposure to practical work (DBE, 2020). The lockdown due to the COVID-19 pandemic has resulted in practical work being conducted online in institutions and Sahu (2020) argues that this has accelerated this transition from contact to online learning. Online practical work means technology is used to carry out this form of practical work. ICT integration in practical work has proven capable of enhancing graphing skills in students (Dori & Sasson, 2008). This study explores how 4th year pre-service chemistry teachers integrates ICT in practical work to interpret experimental data.

1.5 Rationale and Significance of the study

Practical skills are crucial in interpreting data in a science classroom, as some data is represented in inscriptions such as graphs (Bowen & Roth, 2005). Research has previously argued for the need to support pre-service teachers at tertiary level in terms of exploring their abilities in graph interpretations in chemistry, as future science teachers. Education received by pre-service teachers is crucial in rectifying adversities, which plague science teaching and learning. The insight from the teacher educator's perspective is required on how they ensure that students at a tertiary level are equipped with the necessary skills required for graph interpretations. ICT has proven capable of providing opportunities in science education, it is shown to complement laboratory work very well Pernaa & Aksela (2009). ICT affords benefits such as computer-based learning which simultaneously juxtaposes sub-microscopic and symbolic level of molecular representation (Pernaa & Aksela, 2009). Representation of data is not the only benefit of ICT in a learning environment as it promotes critical thinking, active learning and equal opportunities are afforded (Foutsitzi & Caridakis, 2019). Opportunities afforded by ICT in education are beneficial but there remain barriers related to the use of ICT in education. Teachers require training in using ICT for practical work and technical use: Since there exists limitations regarding the use of ICT, if teachers are incompetence in using ICT tools, they lack ability to efficiently use ICT in their teaching thus take unconvincing roles (Foutsitzi & Caridakis, 2019).

The ICT integrated practical work has proven to offer the graphing skills to the students, which are crucial for students to interpret, graph (Dori & Sasson, 2008). Pernaa & Aksela (2009, p. 81) argues that "Chemistry is a difficult discipline to teach and learn, partly because of its three dimensional nature". Graphs are crucial in learning chemistry as they serve as a tool to show relationship between concepts, and this consolidates learners understanding of chemistry concepts (Glazer, 2011). Graphs present data that may be complicated for learners to interpret, and this activity requires graphing skills (Gultepe, 2016). In the existing literature about graph interpretations, little or no attention is given to the extent chemistry content taught links with pedagogy applied and how these are empowered by ICT (TPCK). The graph difficulties can be lessened or eradicated through practical work as it affords learners with the opportunity to follow the scientific method (DBE, 2020). Barriers and benefits of ICT have been explored, however, the conundrum of student's inability to interpret graphs linked to practical skills remains. Studies on perceptions of chemistry teachers and students on the use of ICT in practical work have shown some barriers and benefits. Moreover, less attention is given to how video-mediated practical work enhance graphing skills in chemistry at tertiary education.

This study offered insights on how ICT integrated practical work particularly videos offer the graphing skills to 4th year students in chemistry. This might assist tertiary institutions to gain insight on the role played by ICT integrated practical work to enhance learners graphing skills which are crucial for graph interpretations in turn improving students understanding of chemistry concepts. This will help the science division to make well-informed decision in pedagogically approaching of practical work using ICT with the lenses of TPACK and activity theory. This paper will understand the problem of interpretation of graphs thus exploring possible solutions if any that are afforded by ICT to lessen the ongoing difficulties of graphical interpretation.

1.6 Purpose of the study

The purpose of the study is to explore the extent to which pre-service chemistry teachers integrates ICT in practical work, in order to interpret experimental data. The main question of the study is:

How do 4th year university students interpret experimental data by integrating the use of ICT in Chemistry practical work?

To answer the above main research question, the following sub-research questions were devised.

1. What pedagogical choices are provided for pre-service teachers to expose them to graph interpretations activities in chemistry online practical work?

2. How does the use of video and simulation in chemistry practical work affect 4th year students' ability to interpret graphs?

1.7 Research design

Qualitative data was collected through online classroom observations, interviews and document analysis. During lesson observations the teacher educator delivered a lesson on rates of reactions and chemical equilibrium using videos. The lesson made use of graphs to explain concepts, as well as simulation to show students change in graphical representation in a practical lesson that had graphical related questions that links to content taught. Further, interviews will be conducted with both teacher educators and students to understand the usefulness of ICT integration in chemistry practical. Semi structures questions were used to conduct interviews with pre-service teachers on how ICT integration in chemistry practical work affected their ability to interpret graphs. Document analysis conducted by a way of examining students' practical work with purpose of tracking the adequacy of ICT integration in chemistry practical work particularly to the graphical interpretation related question. Document analysis rely on the activity theory which builds on Vygotsky's work to conceptualise learning to analyse 4th year student's practical work (Isssroff & Scanlon, 2002).

1.8 Chapter outline

This report consists of six chapters. Chapter 1 comprises of a brief introduction and overview of the study which explores ICT integration in chemistry practical to understand the usefulness of

ICT integration in graphical interpretation in chemistry students. A background of the study outlining that the South African school report on the poor performance in physical science in matric for the past years has been associated with lack of exposure to laboratory work for learners to attain practical skills including the concepts of chemistry. The primary question and two secondary questions are stated.

Chapter 2 is comprised of literature review which indicates challenges that are associated with learners' inability to understand the practical components of chemistry when interpreted through a graph. Chemistry is difficult for both students and teachers, and this repels learners from choosing chemistry related studies in future (Sirhan, 2007). Difficulties of learning chemistry are linked to the nature of chemistry and pedagogic approach taken by teachers to teach chemistry (Hussein & Reid, 2009).

Chapter 3 comprises of a theoretical framework, which for this study it is the pedagogical Content Knowledge (PCK) (Shulman, 1986). Technology becoming forefront of education, indicate it can either assist or hinder learning from taking place as it affects pedagogic knowledge of teachers and in turn pedagogy affects content knowledge delivery thus making it difficult to not consider technology as forming interrelationship with pedagogy and content knowledge (Mishra & Koehler, 2006).

Chapter 4 indicates the research paradigm guiding this study is interpretivism. The interpretivist paradigm aligns with this study as it seeks to understand contributions made by students and their interpretive meanings of graphical representations, along with teacher educators' perspective of ICT integration in chemistry practical work. Understanding usefulness of ICT in chemistry practical work generates data that is rich and in-depth analysis, explanation to understand this case, in turn indicating the approach employed by the study which is qualitative approach. Attaining an in-depth explanation of an issue requires a use of case study research design which this study understands the ICT integration in chemistry practical work case, accordingly one case is addressed by this study making it a single-case study. The research is a small-scale study as it understands a case rather than making generalisations. The researcher uses purposive sampling to handpick the sample of five chemistry students fitting categories of lower scorer, middle scorer and higher scorer across three labs (A, B and C). The research instruments videos, document analysis and interviews were considered for data collection.

Chapter 5 is comprised of data analysis which makes use of TPACK translational device to observe the evidence of TPACK in the teaching of rate of reaction and chemical equilibrium. Data collected from research instrument is presented to show major findings of the study.

Chapter 6 comprises of the discussions and conclusions; the paper deduces meaning from data presented in answering the following questions:

1. What pedagogical choices are provided for pre-service teachers to expose them to graph interpretations activities in chemistry online practical work?

2. How does the use of video and simulation in chemistry practical work affect 4th year students' ability to interpret graphs?

Findings from the questions asked are used to draw conclusions about the study.

1.9 Conclusion

Chapter one provided an overview and outline of development of the study. The study is about exploration of ICT integrated practical work with an aim of understanding usefulness of ICT integration in student graphical interpretation skills in chemistry. The Study focuses tertiary education particularly 4th year teacher education programme, to explore the role played by teachers to link content, pedagogy and technology to ensure learners attain practical and graphing skills. This will offer insight to the tertiary institutions to understand the preparedness of novice science teachers in chemistry aspect of graph interpretation through a use of practical work integrated by ICT. This ushers in chapter 2 which presents a literature review of studies previously conducted, predominantly in South African context on the integrations of ICT in practical work for university Science students.

Chapter 2: Literature Review

2.1 Introduction

This chapter presents literature on the use and importance of ICT in teaching and learning as well as its integration in science education. It indicates the debates in literature and progression of chemistry learning, focusing on student challenges about graphs. The challenges are explored with lens of practical work empowered by ICT in science education. The affordances and constraints of ICT integration are discussed to show how ICT may improve the teaching and learning process. Lastly, a theoretical framework is shown as a tool and a guide in this study to analyse and organise findings when ICT is integrated in content taught and practical work particularly observing its usefulness in students' graphical interpretations.

2.2 Chemistry as a science branch: Difficulties in teaching and learning chemistry

Chemistry is difficult for both students and teachers, and this repels learners from choosing chemistry related studies in future (Sirhan, 2007). Difficulties of learning chemistry are linked to the nature of chemistry and pedagogic approach taken by teachers to teach chemistry (Hussein & Reid, 2009). Teaching chemistry means accommodating three level of explaining the concept, which are: macroscopic which refer to descriptive aspect of a concept, sub-microscopic (interpretations) and representational (symbolism) (Hussein & Reid, 2009). According to Santos & Arroio (2016), macroscopic level is basic and corresponds to chemical objects that can be observed either from learners' everyday lives or through practical work, experiments in chemistry, sub-microscopic interpretations or level is real but abstract, and symbolic (representational level), represents a macroscopic phenomenon through a use of chemical equations, analogies, reaction mechanisms and graphs (Santos & Arroio, 2016).They provide the following examples of microscopic, macroscopic and symbolic representations: microscopic representations includes particles illustrations or atoms, a macroscopic representation is indicative of representations such as experiments and experiences and a symbolic representation includes representing a scientific phenomenon using equations and graphs. Competences in coordination of micro, sub-micro and symbolic levels is essential because "chemistry relies on making sense of the invisible and the untouchable" (Tumay, 2016, p,3). Therefore, in the science classroom the teacher should emphasise coordination of three representational level to ensure learners understand chemistry. Santos & Arroio (2016) further argues that learning and understanding of chemistry requires competence in modelling and representational abilities including graph representations. Major difficulties in learning chemistry exists because concepts taught contradict every day and intuitive views of learners, and in turn leave room for misunderstandings, as learners try to comprehend the concepts (Treagust, Nieswandt & Duit, 2000).

Through the incorporation of nature of science in the educative process, learners can understand and accommodate these science concepts, as peculiar, evident based, tentative, falsifiable, and provisional accepted and inconclusive (Chalmers, 2013). Understanding the nature of science is possible through science related activities including science practical work (Vhurumuku, 2010). Nature of chemistry is considered abstract, making it difficult for learners to understand (Woldeamanuel, Atagana & Engida, 2014). Tumay (2016), concurs about the abstract nature of chemistry and assert that it is imperative for teachers' educators to know and understand the nature of chemistry so they may understand students' faulty mental models and misconceptions. Learner's experience difficulties in conceptual understanding in chemistry at secondary level and they progress with this poor understanding to tertiary level where it becomes problematic as students either fail, retake courses or drop out (Yusuf & Ali, 2012). Although conceptual understanding may be a source of learner's poor performance in chemistry, learner's scientific literacy and language have a role in their success (Woldeamanuel, Atagana & Engida, 2014).

Students' common misconceptions about rate of reaction and chemical equilibrium are documented in literature. Misconceptions are difficult to change since they are persistent, ensuring correct conception is essential for initial concepts to allow students to properly understand the subsequent (Jusniar, Effendy, Budiasih & Sutrisno, 2020). A misconception about factors affecting rate of reaction involve a conception that increase in temperature increases activation energy making the reaction faster. A correct conception is that temperature causes a decrease or increase kinetic energy so that the frequency of collisions between the molecules is greater (Hakimah, Muchson, Herunata, Permatasari & Santoso, 2021). Students have a conception that "At dynamic equilibrium rates of forward and reverse reactions vary because amounts of reactants and products also vary," (Jusniar, Effendy, Budiasih & Sutrisno, 2020, p, 1413). The correct conception is that at equilibrium concentrations remain the same due to the nature of irreversible reaction (Jusniar, Effendy, Budiasih & Sutrisno, 2020). Increasing temperature cause a forward reaction to decrease and the reverse reaction rate to increase (Barke et al., 2009). Correct conception is that affect the kinetic energy of particles, increasing collision for products to form if particles collide in right orientation. Addition of a catalyst in a chemical reaction will cause in an increase in concentration of the product (Bilgin &Uzuntiryaki, 2013). Correct conception is that a catalyst does not affect the concentration of the reactants or products in a chemical reaction, it increases the rate of a chemical reaction without being used up.

2.3. Practical work for teacher education

In the educative process, practical work enhances the learning of scientific knowledge, stimulates students' enjoyment and interest (Bradley, 2016). Moreover, for enhancing the nature of science understanding, it gives insights to scientific methods and how to use them and teaches laboratory skills (Bradley, 2016). Practical work is part of the tradition of the science classroom particularly chemistry (Toplis, 2012). It has become part of the tradition because many chemistry teachers perceive practical work as the basic modus operandi for their teaching (Abrahams & Reiss, 2012). Lewthwaite (2014) argues that in a science classroom, practical work has been used in chemistry because it is considered a practical subject although he indicates that it has been criticised as it is carried out, as a matter of convenience, lacking purpose. He adds that the reason for conducting practical work is the role played by the teacher in directing the process and is the emphasis directed at the process skills.

2.4 ICT in science education

ICT has always been treasured as the teaching tool that may facilitate learning. Denby & Holman (2002) indicated that integration to education dates to decades ago, and by the year 2002, there were guides published to show the use of ICT and its benefits in science education (Denby & Holman, 2002). Fu, (2013) concedes that the impact of ICT has since been increasingly notable as it is being successfully applied in instruction, assessment and learning since it is considered an essential tool for change and educational reform, to which Livingstone, (2012) adds that it is because ICT has been known to play a role in enhancing traditional learning outcomes. ICT does not only complement traditional learning environment but has offered alternative learning opportunities such as blended learning, e-learning and online learning (Tayebinik & Putch, 2013). The hybrid instruction that joins the traditional classroom techniques with those of web-based or technological tools is considered a blended learning (Gülbahar and Madran, 2009). ICT offers a range of technological tools such as software programs, data projectors, interactive teaching box, scanners and computers (Pernaa & Aksela, 2009). As much as ICT offers a range of tools, technical knowledge is vital for its successful integration in a science classroom (Twidle & Rogers, 2013). ICT integration affords the educative process with new opportunities as it has proven to make a profound impact on pedagogy (Newton & Rogers, 2001). Integration of ICT in science makes teaching and learning goal-oriented, encourages cooperation, motivates and afford learners with creative opportunities (Lavonen, 2008). Student's interest has shown to be bolstered when ICT Is used in learning rather than just chalk and board teaching style in turn increasing students listening span, improved academic achievement (Kola, 2013).

Science education, particularly chemistry, involves chemical reactions/processes that are very dangerous if not handled with caution (Aina, 2013). Reactions of this nature require students to observe them to gain understanding as it is not easy to understand without seeing them (Aina, 2013). ICT through a use of simulation, videos and other software's allows teachers to explain abstract concepts without putting teachers and learners in harm's way (Abdullahi, 2014). ICT empowered learning shows manipulation of variables to help students understand content taught (Aina, 2013). Students understanding may occur differently as they learn differently (You & Jia, 2008). Abdullahi (2014) argues that ICT may overcome challenges that limits student learning in written forms since it enhances learning environments because learning material can be presented using different ICT tools such as multimedia. Furthermore, multimedia and other ICT tools make it possible for teachers to explore different teaching approaches and methods to make inclusive lessons. He adds that ICT enhance already existing classroom practices and does not re-shape content of the learning area. Complementary of learning by ICT has shown improved interactive nature of teaching, accordingly, promoting students' intellectual qualities through problem solving and higher order thinking (Amajuoyi, 2012).

ICT tools such as computer simulation offers opportunities for students to visualise and work with substances and systems that may rarely be used in actual reality (Jarosievitz, 2009). Moreover, students using simulations may be able to replicate practical work until they attain desired results, in the process learners obtain an enhance understanding of concepts as they experience two knowledges, which is teacher knowledge and computer knowledge (Lavonen, 2008). ICT such as simulation saves times, variables can be manipulated with ease for testing hypothesis and this supports learners understanding with different representations such as graphs (Rutten, Joolingen & Van der Veen, 2012). Blackburn, Villa-Marcos & Williams (2019), show that pre-laboratory simulations have proved to assist students with preparedness for the actual practical. He adds that simulations allow students to manipulate apparatus and as a result students with access to such simulation demonstrate improved practical performance compared to those who do not. With regards to the use of videos, Jolley, Wilson, O'Brien, & Mason (2016), posit that using videos that show experimental procedure as a pre-laboratory activity reduces cognitive overload. Additionally, students psychomotor and affective experiences towards practical work improves significantly when experiment videos were used (Jolley et al., 2016). Loughlin and Cresswell (2021) concede that pre-laboratory preparation activities through a use of videos provide students with supportive information of an underlying rationale and theory for experimental procedures and approaches. They indicate that laboratory activity integration of interactive videos has shown to improve student autonomously and allow students to demonstrate self-regulated learning. Altowaiji , Haddadin , Campos , Sorn, Gonzalez, Villafañe and Groves (2021), concurs as they show that videos have proved impactful during students laboratory activity as they act as a visual thus assist students with data analysis. `

2.5 Various types of ICT integrated practical work

Practical work that is ICT integrated enables a considerable visualization recourse for chemistry teachers (Pernaa & Aksela, 2009). ICT integrated practical work comes in different forms such as microcomputer-based laboratory, computer simulation software (virtual experiment), computer-based molecular modelling, videos and animations (Pernaa & Aksela, 2009). Computer-based molecular modelling allows learners to see connections between three chemical dimensions and in turn develop mental models (Aksela & Lundell, 2008). In a laboratory this software has proven to be an effective tool to complement practical work, as it increases knowledge sharing, communication and it illustrate a chemical phenomenon (Kozma, 2003). Animations represents modelers mental model, are sensitive to graphical expression skills and this makes it difficult to create pedagogically meaningful animations (Pernaa & Aksela, 2009).

Animations practical work allow students to conduct and discuss experiments at a molecular model and improves students' ability to sketch links between macro, sub-micro and symbolic levels of representation developing mental models (Pernaa & Aksela, 2009). Video practical work is efficient practical work to show changes at macroscopic level, they demonstrate experiments safely and are easily accessible at any time (Pernaa & Aksela, 2009). Video analysis can be undertaken in real time, using objects that are real and using data logger with controlling software to be able to record data and engage in practical activity in concurrence with the computer (Rodrigues, Pearce & Livett, 2001). Computer simulation software mediate practical work by allowing learning to use apparatus, decide number of materials or operating conditions and manipulating variables to study relationship of concepts (Denby & Holman, 2002). Simulation in virtual experiments has proven to enhance students' conceptual understanding (Kharki, Bensamka & Berrad, 2020).

2.6 Skills that can be imparted through ICT integrated practical work activities

Graphing skills is about learners plotting points from data, visual perception, logical thinking, deducing the relationship between variables and predicting movement of the graph line points (Gultepe, 2016). Video or simulated practical work offer opportunity for learners to collect and graph their data simultaneously as they observe the scientific phenomenon from the videos (Rodrigues, Pearce & Livett, 2001). This ensures students acquire practical skills during practical work and in turn improves graphing skills in learners. It is not only video or simulation practical work that can offer these practical skills and improve students' graphing skills, but computerized laboratory practical work as well (Dori & Sasson, 2008). Integration of interactive videos in chemistry practical has reinforced acquisition of technical skills for the instrumentation specified, chemical techniques and visualise student's links between techniques learnt with how it could help students develop their knowledge (Loughlin & Cresswell, 2021). These links allow learners to experience real time-graphing which assist learners in graph images interpretation as they are produced in real-time experiments and in turn improves learners graphing skills (Dori & Sasson, 2008). Spreadsheets, particularly excel may complement practical work as it gives computer generated graphs (Denby & Holman, 2002). Students benefit from computer-generated graphs as it allows them to critically look at data. Students may quickly notice the experimental variables changes as they load data (Denby & Holman, 2002). Students may draw graphs with hand with the help of computer-generated graphs (Denby & Holman, 2002). Videos practical work have proven to enhance learners graphing skills when used for observing kinematics quantities (Rodrigues, Pearce & Livett, 2001).

2.7 Reports on challenges associated with graphical Interpretations

National and international literature has reported challenges associated with interpretation of graphs Reports from Croatia on graphical interpretations shows that students suffer from iconic confusion (Ivanjek, Susac, Planinic, Andrasevic & Milin-Sipus, 2016). Iconic confusion consists of student incorrect graphical interpretation as they consider a graph as an actual picture of a motion in science topics such as kinematics (Ivanjek, Susac, Planinic, Andrasevic & Milin-Sipus, 2016). According to Amin, Sahib, Harianto, Patandean, Herman and Hadi (2020), students fail to interpret graphs because they do not understand how read about graphs and how to solve graphical problems. This entails that student do not see the graph as representing a complex relationship between variables on the axis, and it becomes difficult for such students to understand a change in a graph as variables change Ivanjek, Susac, Planinic, Andrasevic & Milin-Sipus, 2016). Similarly, students in Turkey have difficulties in graphical interpretations linked to lack of conceptual understandings and students' misconceptions (Gultepe, 2016). He adds that rules and language about graphs have shown to have an impact whether students comprehend graphs or not.

In Ghana students fail to convey information with graphs and exploiting knowledge offered in graphs (Antwi, Savelsbergh & Eijkelhof, 2018). Telima & Temitope (2013), indicated that countries such as Nigeria endures student difficulties in graphical interpretations, labelling graphs axes and plotting line of best fit. This is problematic because students experience problems with deducing information from the graphs when required to draw inferences (Antwi et al, 2018). Telima & Temitope (2013) reported that drawing inferences from the information offered in graphs is a challenge for students, as they understand to be a picture indicating motion and not a representation indicating a relationship between variables. Practical work and ICT integration has been suggested as a way to help students gain an in-depth understanding of science graphs through a use of interactive simulation and m11icro-computer-based laboratory. In addition, graphs taught through a use of simulations are taught effectively compared to teaching them in a traditional space (Telima & Temitope, 2013). Phage, Lemmer and Hitge (2017) indicate that mathematical reported challenges for South Africa and science graphs may be different even though such subjects are closely related. They acknowledge graphical interpretations difficulties experienced by South African undergraduates and indicate this problem is associated with deficiencies in graphing skills and prior knowledge which in turn retard students' graphical comprehension (Phage, Lemmer & Hitge, 2017). It is shown by Potgieter, Harding & Engelbrecht (2008), that students require substantial conceptual knowledge and spatial abilities if they are to make graphical interpretations or manipulate representations. Although mathematics-chemistry knowledge transfer is valued in assisting students understand chemistry graph (Phage, Lemmer & Hitge, 2017), but the department of education blame lack of practical work exposure in South African learners which results to poor graphical interpretations (DBE, 2020).

2.8 The impact of practical work impact on graphical interpretations

A variety of skills are essential in the 21st century, the most important skill is the ability to work with data (Glazer, 2011). This may allow an individual to find trends, make inferences from the data given, criticise, evaluate data and deduce claims from the data (Gültepe, 2016). Graph representations integrate sets of data, presenting data in concise ways to make sense of data, identifying trends and to illustrate a phenomenon (Glazer, 2011). A human endeavour such as chemical education is complex. It requires deep comprehension of scientific concepts that are diverse and mental transfer between different modes of representation including graphs (Dori and Hameiri, 2003). Graphs are tools that may be used in chemistry to show the relationship that exist between scientific concepts (Gültepe, 2016). Students' proper interpretations and comprehension of the relationship between chemistry concepts, conceptual understanding is directly linked to students' successful interpretations and understanding of graphs (Seçken & Yörük, 2012).

Graphs are used in a science classroom and laboratories as they present knowledge that most datasets cannot present solely (Gultepe, 2016). Glazer (2011) argues that students are experiencing difficulties in graph interpretations in science, including drawing these graphs. The difficulties experienced by learners are include lack of knowledge about rules and language of graphs, additionally its inadequacy in contextually comprehending concepts. Moreover, it is problems related to defining variables presented and linking graphs with these variables, and lastly it is prior knowledge of a graphs content (Gultepe, 2016).Undergraduates' students are experiencing difficulties in graph interpretations for chemistry due to inadequate graphing skills and in turn students fail to benefit from the potential offered by reading graphs (Kilic, Sezeni & Sari, 2012).

2.9 Conclusion

Literature explored in Chapter 2 has revealed that ICT integration in practical work proves crucial in students acquiring skills such as practical and graphing skills. It has shown the importance of acquisition of skills in understanding representations in graphical forms, struggles faced by students linked to lack of knowledge, inadequacy in contextually comprehending concepts, and linking graphs variables. The next chapter discusses the theoretical and conceptual underpinnings for this study.

Chapter 3: Theoretical framework

3.1 Introduction

This chapter reveal the lens used to make sense of data in a form of a theoretical framework for the study. The study uses a theoretical framework of PCK which arising from this theory is TPACK. TPACK is a conceptual framework for this paper that aligns with the study as knowledge taught in rate of reaction and chemical equilibrium are explored to an extent at how these (content taught) link with pedagogy applied (practical work), accordingly evaluating how these two are empowered by ICT. The origin of the theoretical framework is examined and how it gave birth to conceptual framework TPACK.

3.2 The Pedagogical content knowledge

The theoretical framework for this study is the pedagogical Content Knowledge (PCK) (Shulman, 1986). Pedagogical content knowledge includes an understanding of what makes the learning of specific topics easy or difficult (Shulman, 1987). This framework was a result of a motivation on how teachers assimilate a piece of text and transform their comprehension of it into instruction that their students can understand. Accordingly, Shulman inadequacies in teacher knowledge comprise of pedagogical knowledge (PK) and subject matter knowledge with little or no evidence of how these categories are related (Shulman, 1986). The diagram below shows Pedagogy and Content as knowledge domains that exist without any interrelatedness.

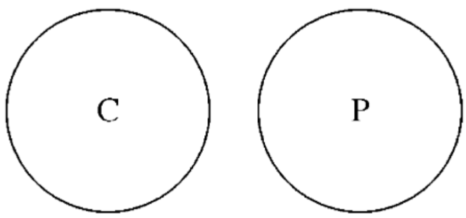

Figure 1: Circles of pedagogical and content knowledge (Mishra & Koehler, 2006)

Shulman argued for the interrelatedness of pedagogical and content knowledge which gave birth to the idea of pedagogical content knowledge (PCK). This emphasised the point that for teachers to be successful they must confront both issues of pedagogy and content knowledge concurrently by realising the teachability of content (Shulman, 1987). The relationship of mutual exclusivity in pedagogical and content knowledge repercussions on educational domain were programs that were either focused on the subject matter content or pedagogical knowledge (Shulman, 1987). Among the categories of content knowledge, pedagogical content knowledge is essentially crucial in identifying different bodies of knowledge in educational process. It is constituted of the blend of pedagogy and content knowledge for comprehending how issues, problems or topics are represented, organised, and transformed for instruction resulting to learners understanding what is instructed (Shulaman, 1987). This illustrates PCK to be a notion that presents a working relationship between pedagogical and content knowledge explaining teachers' ability to interpret subject matter content knowledge (SMK) and accordingly devise methods to make it accessible to students by representing this knowledge (PK). Concurring literature by Kind (2009), suggests that teachers transform SMK using a powerful notion of PCK. The diagram below shows the notion of PCK which blends pedagogical and content knowledge.

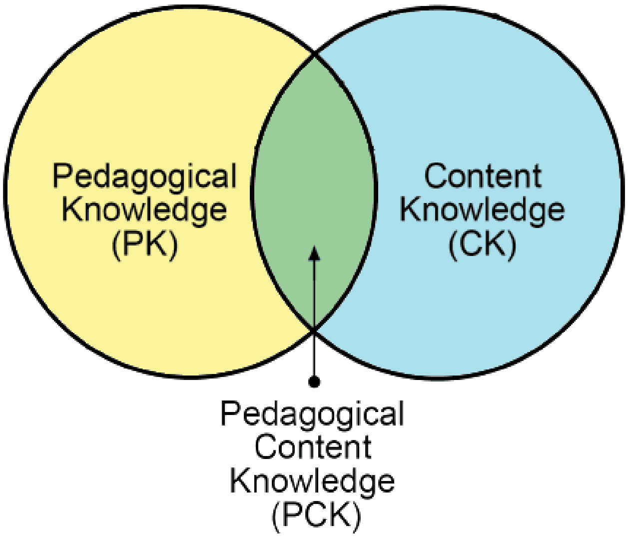

Figure 2: The interrelatedness of pedagogical and content knowledge which this blend represents PCK

PCK for a chemistry topic may not necessarily the same as PCK for a Physics topic (Vaal & Makinster, 1999). The focus of this study is focused on the Chemistry component of the Physical science curriculum and acknowledges that there are specific content and pedagogy related aspects of chemistry that are different from the physics component. This implies that the way it is taught and learned will be different and requires certain unique skills. Specificity of PCK suggests that PCK notion is generic and tacit and in turn indicates a need for more specific nature of PCK that is sharply defined. Mavhunga & Rollnick (2013), argues for recognition of a topic specific PCK nature which lean in the ability to transform concepts in a domain but specifically within a topic by packaging them for instruction. PCK considers different forms of knowledge for teaching, as it refers ability of teachers to transform and interpret the subject matter knowledge for purposes of facilitating learning (Angeli & Valanides, 2008). Accordingly, PCK encompasses an understanding of preconceptions held by learners along with difficulties and involve forms of representation, analogies, demonstrations illustrations and variety of useful ways to formulating and representing the subject in ways that are understandable by learners (Angeli & Valanides, 2008). The topic of reaction rates and chemical equilibrium are the focus of this study. This is because these topics comprise of practical activities whose results need to be represented and interpreted graphically. To enable learners to better understand the topics especially making a relationship between the theory, practical activities and its representation in graphs, the use of technology resources can become useful.

Mishra & Koehler (2006) argues that technology plays a pivotal role in subject matter knowledge representations thus making it accessible to students due to the affordances granted by technology. This emphasises that even though PCK shows a blend of pedagogical and content knowledge, a third triangle of technology exist separate to these forms of knowledge. Lack of awareness might have contributed to little or no evidence of technology and PCK interactions. Interactions between Technology is worthy of consideration according to Mishra & Koehler (2006, p, 1023), as technologies "have come to the forefront of educational discourse primarily because of the availability of a range of new, primarily digital, technologies and requirements for learning how to apply them to teaching". Technology has always been part of education but have in a past considered "common place and were not regarded as technologies" (Mishra & Koehler, 2006, p. 1023).

The need for technology in educational programmes has intensified even at recent times due to pandemic such Covid-19 accelerating the transition from traditional classroom to blended classes and even fully online learning programmes (Lemay, Bazelais & Doleck, 2021). Technological issues in relation to PCK may have not been undermined in the times of Shulman but at a time technology may have not been part of mainstream yet. Mainstream does require usage of technology as time progressed. Angeli & Valanides (2008) argues that technology has an essential role in aspects of content transformation, making it accessible to students as it affords range of analogies, representation, explanations, demonstrations, and examples to clarify issues of subject matter. Links between subject matter and pedagogical knowledge imply there is a relationship between these bodies of knowledge, however this is not considered in the notion of

PCK. The diagram below illustrates circles for content and pedagogical knowledge as separate to technology and its skillset.

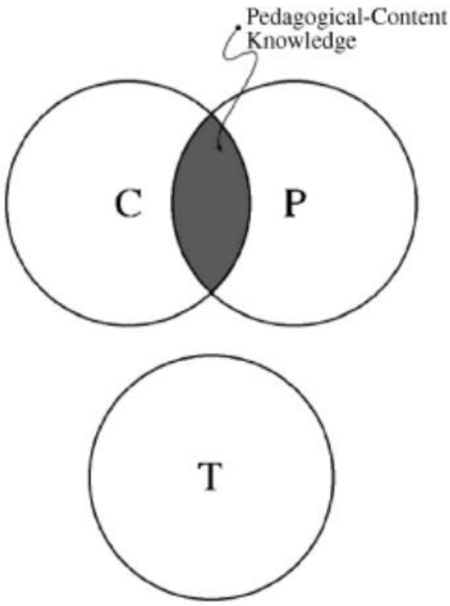

Figure 3: Circles of a blend of content and pedagogical knowledge (PCK) as separate to technological knowledge Mishra & Koehler (2006).

Mishra & Koehler (2006) argue that technology is complex requiring training and competency. Technology becoming forefront of education, indicate it can either assist or hinder learning from taking place as it affects pedagogic knowledge of teachers and in turn pedagogy affects content knowledge delivery thus making it difficult to not consider technology as forming interrelationship with pedagogy and content knowledge (Mishra & Koehler, 2006). This gives rise to a complex interplay of technological, pedagogical, and content knowledge (TPACK), as these three bodies of knowledge re central to successful instruction. The conceptual framework guiding this study is technological pedagogical content knowledge. Technological pedagogical content knowledge (TPACK) is a sophisticated knowledge which allows the complex interplay involving three knowledges firstly, content knowledge (CK) which is the knowledge of subject taught (Raman, 2014). Secondly, pedagogical knowledge (PK) to apply, which is the knowledge of teaching, such as methods and strategies and lastly, the technology knowledge (TK) to empower the first two (Raman, 2014). Successful integration of technology requires a use of this framework called TPACK (Angeli & Valanides, 2009). This study uses this framework as lens to understand the use of ICT integration in chemistry practical work. It explores the content taught (CK) to understand chemistry concepts relationship that will be examined during each practical session. The practical session will indicate pedagogy applied (PK) in a form of practical work and ICT integration (TK) will be considered to understand the usefulness of ICT in practical work forming the interplay of the three knowledges (CK, PK, TK).

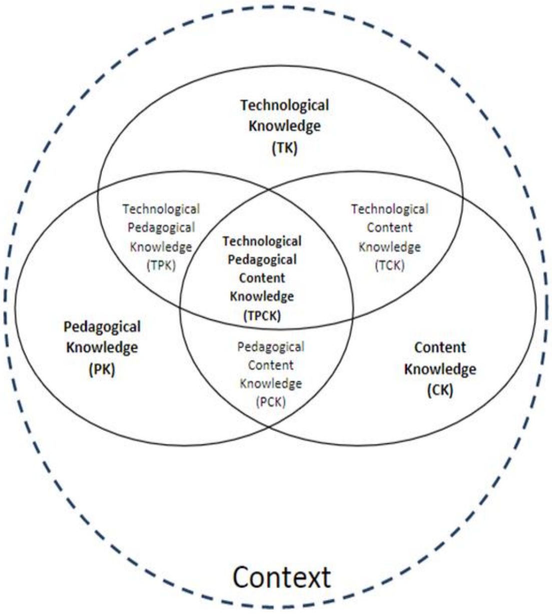

Figure 4. *Technological Pedagogy Content Knowledge (Chai, NG, Hong & Koh, 2013, p, 42)*

Complementary to TPACK, an activity theory is used hand in hand to show students perspective of ICT integration. Relationship between TPACK and activity theory is that TPACK is a tool exploring content taught, whereas activity theory examines how learning takes places in students after content was taught. This permits the study to explore the activity, which is practical work, with an intention of understanding how it allows students to access practical and graphing skills. Measuring students' evaluated work and responses was used in this study to decide the outcome of using ICT as a tool in learning to assist students with graphical comprehension (Isssroff & Scanlon, 2002). Activity theory builds on the work of Vygotsky and is used to conceptualise learning observing relationship between tool, subjects, objects, community, rules and division of labour (Isssrof & Scanlon, 2002). In this study a tool is ICT, subjects are 4th year chemistry students, object is the chemistry practical work, community is chemistry particularly rate of reaction/chemical equilibrium, rules are rules and language of comprehending graph related content. lastly division of labour refers to how work is shared between teacher educators and tutors to prepare and support students.

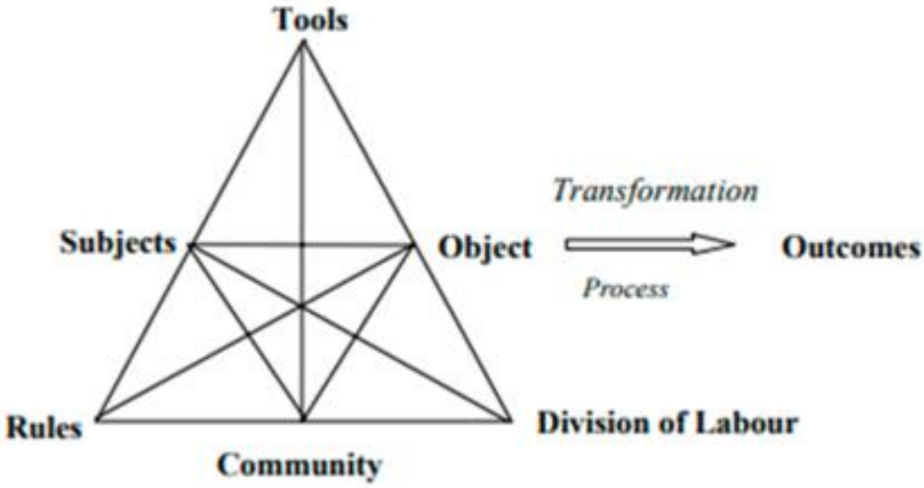

Figure 5. The relationship between codes used in activity theory.

3.3 Conclusion

This chapter outlined the conceptual framework employed in this study. TPACK is comprised of codes such as PK, TK, CK, TPK, TCK, PCK, TPCK to analyse the teaching and learning allowing the study to understand teachers attempt to teach content and conduct practical work when ICT is integrated. Codes reflected by the activity theory are tools, subjects, object, rules, community and division of labour. Activity theory is used hand in hand with TPACK as tools to understand teachers and students' experiences of ICT integration on how it can aid students' graphical comprehension. The next chapter outlines the methodology for this study.

Chapter 4: Methodology

4.1 Introduction

This chapter makes known the paradigm guiding this study to provide a clear understanding of how the topic is approached ontologically, epistemologically and methodologically. Then it explains the research approach used by the study. This makes clear the research design and the method used to shape how this study was conceptualised, conducted and reported. It shows the research sampling, and the sample method the study used to select the sample and indicate the scale of this research. It then covers how the TPACK, and activity theory is used to analyse data and lastly indicate the ethical considerations for this study.

4.2 Research Paradigm

A research paradigm is a set of metaphysical and scientific beliefs that comprises a theoretical framework, which theories that are scientific can be tested, evaluated, and revised if necessary (Phothongsunan, 2010). A research paradigm guiding this study is interpretivism. Interpretivism may result to high-level validity in collected data as it based on contributions that are personal with consideration of different variables (Myers, 2008). This paradigm allows consideration of variety of factors such as behavioural aspects of the participants experiences, and this is essential in describing reality (Alharahsheh & Pius, 2020). This indicates that the paradigm seeks to understand the complex nature of the social world which cannot be reduced to relationships between a small number of variables (Pothongsunan, 2010). Moreover, it allows researchers to treat the situation and research context as different considering participants involved and circumstances associated (Alharahsheh & Pius, 2020). This shows that this paradigm may accommodate human change over time and not constructing same type of generalisability claims (Pothongsunan, 2010). It guides the research to be focused on the topic rather than making generalisations as done in positivism paradigm (Alharahsheh & Pius, 2020). The cons of Interpretivism paradigm are that reality is multi-layered thus, conclusions can vary depending on the assumptions and beliefs of the researcher (Pothongsunan, 2010).

Interpretivist paradigm is about understanding the subjective world of human experience (Alharahsheh & Pius, 2020). This approach seeks to interpret and understand what the subject is thinking or the meaning s/he is making of the context (Alharahsheh & Pius, 2020). Ontology, places emphasis on understanding the individual and how they interpret the world around them, reality in this theory is socially constructed (Alharahsheh & Pius, 2020). Epistemology of interpretivism is subjective providing a clear link between participants and the research as it entails that human cannot be separated from their knowledge (Saunders, Lewis & Thornhill, 2012). This aligns with this study as seeks to understand contributions made by students and their interpretive meanings of the graphs. This is explored from the practical work point where students are engaged in a scientific procedure and therefore find relationship of concepts through interpreting graph representations. Teacher educators attempt to use ICT will be explored on how they complement the practical work and theory/content taught. This paradigm contributes to this study because it caters a small-scale study therefore guiding this study not to generalise out of data collected but to understand the issue of ICT integration in chemistry practical work.

4.3 Research Approach

The approach adopted by this study is qualitative approach. Qualitative approach offers an opportunity for researchers to engage with data to provide rich and in-depth explanations to understand a phenomenon (Patton, 2005). Qualitative approach generates words, rather than numbers (Williams, 2007). The qualitative methods aim to understand the phenomena using an in-depth and detailed aspect of data (Cohen & Morrison, 2007). The study is qualitative, the research questions of this paper are qualitative questions, meaning an in depth and more detailed response is required. The study is built on inductive reasoning as it attempts to address a case of ICT integration chemistry practical work. It unpacks on the usefulness of ICT in chemistry practical work with lenses of TPACK and AT. This is done through a formulation of two questions: one for teacher educators and another for 4th year chemistry students. Responses to these questions are in-depth as they act as data that should be sufficient to address the case at hand. Tertiary level content instruction and practical work were explored on how they link, and the central focus was on the integration of ICT in chemistry practical work with an aim of looking at the contribution of practical skills attained in students' ability to interpret graphs.

4.4 Research Design

This study is a case study. A case study is about investigation of an issue which can be explored through a single or multiples cases within a bounded system (Cresswel & Poth, 2013). This study is a single case as it explores the issue of graph interpretations and how students acquire practical skills to improve graphing skills from practical work when there is an integration of video ICTs. A case study is useful when there is a need to attain an in-depth exploration of an issue, phenomenon, or event of interest, in its natural authentic context (Crowe, Cresswell, Robertson, Huby, Avery & Aziz Sheikh, 2011). This study is a single case about ICT integration in chemistry practical work during a defined timeframe. ICT integration in chemistry practical with an aim of understand its usefulness to graphical interpretations is a poorly understood problem (Nakhleh, Polles & Malina, 2003). The case study plays a role in the structure of this research project as it follows the setup of starting with problem, then context, the issues, and the lessons learned (Williams, 2007). A case study data collected is extensive and thus draws from different sources such as pre-recordings, interviews, and participants (Williams, 2007). This study follows a case study as it was required to collect data from participants who were teacher educators and students. Additionally interviews and document analysis were used to strengthen the data to understand usefulness of ICT integration in chemistry practical work towards 4^{th} chemistry students' graphical interpretations. This approach allowed this study to provide an in-depth appreciation of graph interpretations difficulties in chemistry on how practical work contributes to overcoming these difficulties.

4.5 Research Sampling

The study population is a small-scale, this is because this study sole aim is to understand a case rather than making generalisations from the findings (Forman, Creswell, Damschroder, Kowalski, & Krein, 2008). A well detailed study of a phenomenon entails in-depth and intensive exploration of a small sample as opposed to large sample findings (Forman, Creswell, Damschroder, Kowalski, & Krein, 2008). The research sampling used in this study is a purposive sampling method. Cohen and Morrison argue that for a purposive sampling "researchers handpick the cases to be included in the sample on the basis of their judgement of their typicality or possession of the particular characteristics being sought" (Cohen & Morrison, 2007, p, 115). Purposive sampling is used for this study because it is a small-scale study. Understanding the case explored in this study it is crucial to handpick the sample matching characteristics required for this research topic. The sample consists of a teacher educator and his or her students. A maximum of 5 students were required for One group based on their year of study 4th year and performances lower, middle and a high scorer. The selection was based on student's performance in ICT integrated chemistry practical work, which led to the three categories:

Category 1: 4th year Students that are lower scorers in the chemistry practical work.

Category 2: 4th year Students that are middle scorers in the chemistry practical work.

Category 3: 4th year students that are higher scorers in the chemistry practical work.

The total number of students selected were five, two students that were highest scorers across three labs from Lab A and Lab C, two students that were average across three labs selected from Lab B and Lab C. One student that was the lowest across three labs, selected from Lab B. Initially the intended selection of lower scores was two, due to lower scorers hesitant to participate for reasons of not scoring higher became a barrier and in turn one lower scorer participant was willing to participate across three labs.

This study explored practical work when ICT is integrated, which is now used at tertiary due to contact-online transition as result of COVID-19. Moreover, Chemistry is chosen due to the poor academic achievement of learners in science, particularly in chemistry. The 4th year level of study is chosen to explore the extent teacher educators ensure the preparedness of these pre-service teachers as they will be going to the field, to teach the same students who are experiencing the difficulties in chemistry. The chemistry teacher educator was a single teacher educator, and 5 students will be chosen based on their academic performance in chemistry practical work. In each three-laboratory group students were chosen, where 1 is a lower scorer, 2 middle scorers and 2 high scorers. The study chose one lower scorer because the study wishes to understand the difficulties in graphical interpretations and how ICT integrated practical work can be useful in this problem.

4.6 Data Collection

4.6.1 videos

The study observed two lecture recordings lessons for the exploration of content focusing on how relationships of the rate of reactions and chemical equilibrium are taught by examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge and content knowledge complex interplay. The TPACK interplay allowed the study to understand if content taught links with pedagogy applied (practical work) and how these two are empowered by ICT, accordingly, determining the usefulness of ICT integration in students' graphical interpretations. Recording or videos are popular in data collection for researchers. The reason for using videos is that it allows a researcher to review the moments in the video repeatedly to get accurate information, it allows examination of the downstream and lead-up results of the critical event. It preserves more aspects of talking, gesture, computer displays, and manipulatives which are crucial aspect when collecting data for analysis (Roschelle, 2000). These advantages show the importance of using videos as a source for data collection, as the study is focusing on ICT integration in chemistry practical work. The exploration of content focusing on how relationships of rate of reactions and chemical equilibrium are taught by examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge and content knowledge complex interplay. The TPACK interplay allowed the study to understand if content taught links with pedagogy applied (practical work) and how these two are empowered by ICT, accordingly, determining the usefulness of ICT integration in students' graphical interpretations. However, it has disadvantages which is that they are time consuming when transcribing (Roschelle, 2000). Videos can be used inappropriately as a researcher may pick moments that appear best and may overlook important events. A video may not include all the moments of the lesson (Roschelle, 2000).

4.6.2 Interviews

Integration of ICT in practical work was considered by conducting interviews to understand pedagogical choices that are provided by the teacher educators to expose students to graph interpretations activities in chemistry during online practical work. Interview gathers description of participants with regard to interpretation of meanings of the phenomenon in question (Alshenqeeti, 2014). Concurring, description of participants recorded during interviews are in depth information about a topic in which a phenomenon can be interpreted with regards to meanings acquired from participants (Schostak, 2006). Interviews can be categorised into structured, semi structured and unstructured (Pothongsunan, 2010). The unstructured interview means a researcher does not have a prepared set of questions whereas a structured interview uses a fixed set of questions (Pothongsunan, 2010). The set of questions for semi-structured may be loosely as there are less constraints because a researcher has a set of questions with a room to add more questions if necessary (Pothongsunan, 2010). This study used a semi-structured interview as they were conducted on students to analyse how does ICT integration in chemistry practical work at 4th year level chemistry affect students' ability to interpret graphs. The researcher had room for developing ideas during the interviews conducted. This allowed the study to explore in-depth the pedagogical choices provided for pre-service teachers to expose them to graph interpretations activities in chemistry online practical work. Accordingly evaluate this information from the content taught and ICT integrated practical conducted by 4th year chemistry students. Interviews were considered for students because the study intended to understand. How does the use of video and simulation in chemistry practical work affect 4thyear students' ability to interpret graphs.

4.6.3 Document analysis

Document analysis is a procedure (systematic procedure) for evaluating documents that are electronic or printed material (Bowen, 2009). Document for research purposes could be any document related to a topic explored such as newspaper, institutional reports, scripts from the television and books (Bowen, 2009). Documents that were used for this study are scripts of 4th year students' chemistry practical work. The documents were obtained from the institutions online learning platform with the permission of the schools' authorities. Document analysis involves selecting, finding, making sense of information and produce data that is found in the documents; accordingly. This data is presented as categories, quotes, or themes (Labuschagne, 2003). Making sense of document analysis data require data to be interpreted, examined so meaning can be elicited, allowing a researcher to develop knowledge that empirical and in turn gain understanding (Corbi & Strauss, 2008). Data from document analysis may contain information in a form of images or words which may have been recorded without intervention of a researcher (Bowen, 2009). The information contained in documents for this study was evaluated graphical related questions of students. The data contained from the documents were arranged by the researcher according to categories lower scorer, middle scorer, and higher scorer. They were interpreted based on ICT integration usefulness on graphical interpretation of experimental data provided there is evidence of TPACK interplay in lesson and links between content taught with chemistry practical work done.

Document analysis is often used in coordination with other research instruments for a purpose of triangulation, increasing credibility of data as the same phenomenon is explored (Bowen, 2009). In this study the document analysis was used hand in hand with interviews, video analysis for data evaluation purposes. Impact of ICT integration was examined by evaluating 4th year chemistry practical work for the participants and therefore making meaning of this evaluation using data collected in the interviews and analysis of lecture recordings. Conclusion from the three instruments increase credibility of the data allowing the study to conclusively answer the main research question of How do 4th-year university students interpret experimental data by integrating the use of ICT in Chemistry practical work.

4.7 Data analysis

In this study a thematic analysis by Braun and Clarke (2006) was used for identifying, analysing, organizing, describing, and reporting themes found within a data set. A thematic analysis is a qualitative research method that can be useful to construct insightful and trustworthy findings

(Nowell, Norris, White & Moules, 2017). The thematic analysis was used to identify the concepts taught during the lesson for 4th year chemistry course. Moreover, to organise content taught in a table form to note the relationships between concepts. The organisation of the relationship between concepts allowed the study to understand which relationships are explored in each practical work session. The table was construed with five categories to show a summary of key features of data collected from rate of reaction and chemical equilibrium lesson. The categories are time, instruction, theory/content, TPACK component present and episode. The first category indicates the segment of the lesson using time in minutes, it shows the moment of occurrence from the lesson. The instruction section considers moments of the lesson where a teacher direct learners' actions in a classroom such as when asking questions about the content or asking them to take notes. Theory or content considers knowledge about rate of reaction and chemical equilibrium from a lesson where a teacher introduces a concept unpacking it or packing it. The content/theory shows components of TPACK as the teacher educators instructs thus these components are identified in each segment and are indicated in the evidence of TPACK component category. Lastly there is a section for an episode indicating of more than 1 component of TPACK. An example is shown below in table 1.

Table 1: Example of a thematic analysis

Time in minutes	Instruction	Theory/content	TPACK component present	Episode
44:14 – 52:45	Students are instructed to observe and ask questions in relation to concepts discussed.	OK all right, so we are now here we are saying when we are starting with the reaction we start with high concentration of reactants and then with time as these reactants are actually being used. They are forming products as you can see here in the concentration of the of the reactants is decreasing as the time goes on I think maybe it is there is nothing or there's very very few (Referring to a visual with a graph). So when you come to this side now here the reaction now is no longer as fast as the beginning because the particles reacting are very few and now they are far apart and the collisions which should take place are very very minimal so hence now that's why you will find out that the rate of a reaction will always be slowing down if it's not a reversible reaction it goes to completion, if it is a reversable reaction it doesn't go to 0.	CK, TK, TCK, PK, TPK, PCK, TPCK	1

		This is because the particles which we started with the concentration were high that is the number of moles per unit volume were high right but as we go on the number of moles per unit volume is decreasing by second by each second why? Is because they're being transformed or the reaction is actually producing reactants so it is now the reactions which are in higher concentration than the product so you this is now how you should express your diagram is the reaction is progressing the rate of reaction decreases and why does it decrease it is because of this issue here……(Rest of the episode is shown in the Appendix A).		

Table 2 below shows a translation was developed for rate of reaction and chemical equilibrium lesson analysis:

Table 2: The TPACK Translational Device

Code	Indicator
CK	Content Knowledge: Knowledge of subjects to be taught (eg, Physics, Chemistry, Geography). Shulman (1986) defines content knowledge as the knowledge of facts, concepts, and structure of a subject area, as well as the ways in which the truth and falsehood, and validity and invalidity within that content area, are established.
TK	Technology knowledge refers to the knowledge about various technologies, ranging from low-tech technologies such as pencil and paper to digital technologies such as the Internet, digital video, interactive whiteboards, and software programs
PK	Pedagogical Knowledge: Knowledge of the art of teaching, including methods, teaching techniques and strategies, classroom management skills and planning teaching sessions. It also includes knowledge assessment and evaluation along with student learning (Koehler & Mishra, 2005).
TPK	Technological Pedagogical Knowledge: Knowledge for using technology to implement a teaching method. For example, TPK can be exhibited by knowing how to effectively use a digital camera in the classroom or knowledge of effective online teaching (Cox, 2008).
TCK	Technological Content Knowledge: Knowledge of the relationship between subjects and technology, including the knowledge related to appropriate technology to be used to explore a content area discipline. The choice of technologies affords and constrains the types of content ideas that can be taught. For example, an animated simulation may be useful in teaching language and arts concepts like grammatical rules. Furthermore, technological tools can provide a greater degree of flexibility in navigating across these representations (Koehler & Mishra, 2008).
PCK	Pedagogical Content Knowledge or PCK: Knowledge of the pedagogy or the teaching practices that are appropriate for a subject. This also includes knowledge of pedagogical methods, knowledge of the challenges any given area presents, as well as an understanding of students' preconceptions and misconceptions

	regarding a specific area content. Expertise in a particular area involves more than problem-solving skills and knowing the content (Bransford, Brown, and Cocking, 2000)
TPCK	Technological Pedagogical Content Knowledge: Knowledge of the complex interaction among content, pedagogy and technology.

In order to determine the evidence for TPACK, three categories were established ranging from simple TPACK episode to sophisticated TPACK. This was used to determine the extent at which the teacher is aware of TK, PK and CK interplay as this allow a teacher to ensure students have a sound understand of rate of reaction and chemical equilibrium. This makes it easier for students to be better prepared for the ICT integrated practical work.

Table 3: Evidence of TPACK

Simple TPACK Episode	Proficient TPACK episode	Sophisticated TPACK episode
Evidence of two TPACK components interacting and distinguishably in single episode.	Evidence of 3 – 4 TPACK components interacting and distinguishably in single episode.	Evidence of 5 - 7 TPACK components interacting and distinguishably in single episode.

4.8 Rigor

The results validity and trustworthiness have been thoroughly considered in this study. There were meetings where data translational devices and coding were presented, criticised and developed. The coding for episodes used in this study were agreed upon by a research group using the same research framework as part of data triangulation.

4.8.1 Reliability

The data was transcribed as it was collected from the rate of reaction and chemical equilibrium videos. The video transcripts and links to the videos used in this study will be submitted along with the study as part of the appendix as point of reference for my data. The data was organised in a table as part of thematic analysis for each lesson and this information was coded using a translational device which is shown in figure 5. The interviews and practical work analysis supported this data to strengthen the argument. The data was analysed using coding that were consistent with the translational devices constructed.

4.8.2 Validity

The data collected was explored in the lenses of two frameworks which is TPACK, and activity theory and the findings were consistent even though different theories are used. This strengthens the validity of the data used in the study. The data was presented to fellow students that use the same research framework to triangulate data and have a critical look at the use of theoretical frameworks for data analysis.

4.9 Ethical Considerations

Confidentiality will be minimized to protect the participants by putting proper safeguards in place to protect the privacy of participants and their information from unauthorized access, use, disclosure, modification, loss, and theft. Anonymized information use will be adopted through stripping of all personal identifier that and where both the risk of reidentification from remaining indirect identifiers is low, and where no codes exist that could allow participants future links to data. Participants will receive an informed consent clearly stating the objectives of this study, the summary of the research proposal. Examining the lecture recording, the study will use pseudo names of the participants in the data analysis and since the study focus is on how ICT is integrated in practical work, and the attempts made by the teachers to ensure learners acquire practical skills and are assisted during this activity, the ethical dimensions of confidentiality and anonymity will be minimized.

4.10 Conclusion

The research paradigm guiding this study is interpretivism. The interpretivist paradigm aligns with this study as it seeks to understand contributions made by students and their interpretive meanings of graphical representations, along with teacher educators' perspective of ICT integration in chemistry practical work. Understanding usefulness of ICT in chemistry practical work generates data that is rich and in-depth analysis, explanation to understand this case, in turn indicating the approach employed by the study which is qualitative approach. Attaining an in-depth explanation of an issue requires a use of case study research design which this study understands the ICT integration in chemistry practical work case, accordingly one case is addressed by this study making it a single-case study. The research is a small-scale study as it understands a case rather than making generalisations. The researcher uses purposive sampling to handpick the sample of five chemistry students fitting categories of lower scorer, middle scorer and higher scorer across three labs (A, B and C).

The research instruments videos, document analysis and interviews were considered for data collection. The study observed two lecture recordings lessons for the exploration of content focusing on how relationships of the rate of reactions and chemical equilibrium are taught by examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge and content knowledge complex interplay. The TPACK interplay allowed the study to understand if content taught links with pedagogy applied (practical work) and how these two are empowered by ICT, accordingly, determining the usefulness of ICT integration in students' graphical interpretations. The information contained in documents for this study was evaluated graphical related questions of students. The data contained from the documents were arranged by the researcher according to categories lower scorer, middle scorer, and higher scorer. They were interpreted based on ICT integration usefulness on graphical interpretation of experimental data provided there is evidence of TPACK interplay in lesson and links between content taught with chemistry practical work done. Integration of ICT in practical work was considered by conducting interviews to understand pedagogical choices that are provided by the teacher educators to expose students to graph interpretations activities in chemistry during online practical work. The study used thematic analysis.

The thematic analysis was used to identify the concepts taught during the lesson for 4th year chemistry course. Moreover, to organise content taught in a table form to note the relationships between concepts. The organisation of the relationship between concepts allowed the study to understand which relationships are explored in each practical work session. The results validity and trustworthiness have been thoroughly considered in this study. There were meetings where data translational devices and coding were presented, criticised, and developed. Reliability was ensured by considering more then one research instrument. Two conceptual theories were adopted to ensure validity of data. Confidentiality was maintained by putting proper safeguards, anonymized information was used stripping of all personal identifier.

5. Chapter 5: Result Presentation

5.1 Introduction

This chapter provide an insight on the analytical strategy used in this study, as it explains how data collected was analysed and introduces TPACK translational devices. Moreover, presentation of results is done to show concepts explored during the rate of reaction and chemical equilibrium lessons. The lesson analysis was narrowed to concepts to be explored during the online practical work, particularly concepts linked to graphical related questions. This chapter show how content knowledge links with pedagogy applied in the form practical work and how they both empowered by ICT. Activity theory was used to present students evaluation of graphical related questions. Thus, TPACK and activity theory are used as tools to understand useful of ICT integration in students' graphical interpretations challenges.

5.2 Theme 1: TPACK as lens to understand concept taught and teacher educators pedagogical choices in approaching practical work.

Summary of Theme 1:

Theme 1 explores the content focusing on how relationships of the rate of reaction and chemical equilibrium are taught by examining the evidence of TPACK as an attempt to understand teacher educators' awareness of the technological knowledge, pedagogical knowledge, and content knowledge complex interplay. This theme involves analysis of two lessons namely rate of reaction and chemical equilibrium which are examined using episodes. An episode is a lesson moment that is an exploration of concepts to be discussed during the practical work and these moments TPACK evidence is explored. The relationship between the two topics is briefly explored.

5.2.1 Reaction rate Lesson analysis:

The rate of reaction content delivery was synchronously via MS Teams indicating the use of technological pedagogical knowledge. The teacher educator uses Ms Teams to present power point slide of rate of reaction content for effective online learning thus resembling TPK. This synchronously presentation of the lesson allows easy integration of visuals and simulations to engage students thus indicating competency in using technology to implement a teaching method (TPK). To explore evidence of TPACK the study considers lesson moments that are related to graphical questions explored during practical work. Figure 6 below shows a lesson moment for rate of reaction lesson.

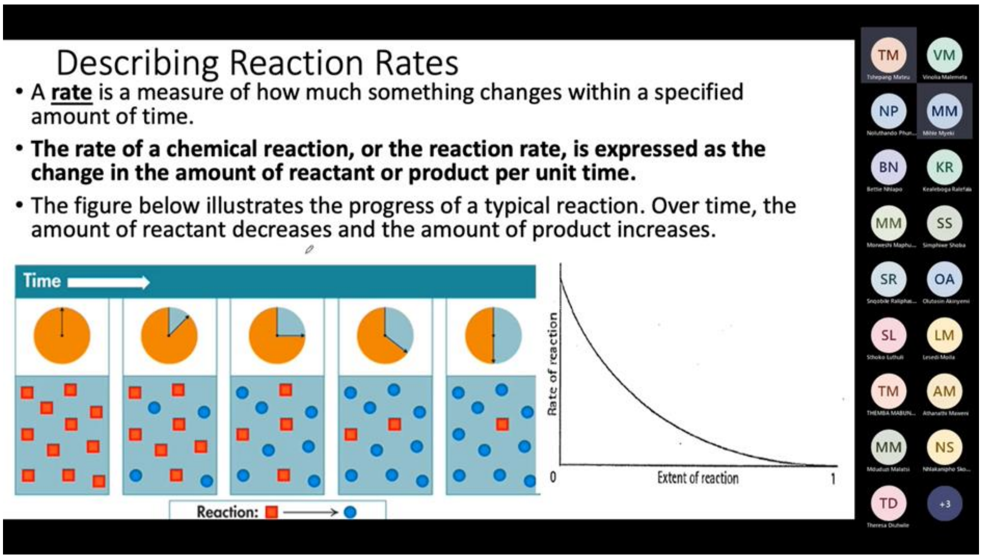

Figure 8: A lesson moment for rate of reaction, illustrating rate of reaction graphically and using molecules.

Summary of the lesson moment:

Rate of reaction is an abstract topic and require visuals and graphs to make this content accessible to learners since particles or molecules of substance cannot be seen with naked eye. In this lesson moment/episode the teacher educator describes the rate of reaction using definition/factual knowledge and accordingly uses diagrammatic representation of molecules and a graph showing the reaction progression, making content accessible to students. In describing reaction rate the teacher shows components of TPACK, this is analysed below considering the teacher' educators' explanation for figure 8. Above.

> "Lecture: *Hence now that's why you will find out that the rate of a reaction will always be slowing down if it's not a reversible reaction it goes to completion, if it is a reversable reaction it doesn't go to 0. This is because the particles which we started with the concentration were high that is the number of moles per unit volume were high right but as we go on the number of moles per unit volume is decreasing by second by each second why? is because they're being transformed or the reaction is actually producing reactants so it is now the reactants which are in higher concentration than the product so you you this is now how you should express your your diagram is the reaction is*

progressing the rate of reaction decreases and why does it decrease it is because of this issue here (referring to a graph)."

The teacher educator shows the component of content knowledge (CK), to explain the concept of rate of reaction as the change in the amount of reactant or product per unit time. Moreover, concentration is defined as the "the number of moles per unit volume". This indicate the content knowledge as this is a knowledge of facts, concepts, and structure of a subject area, as well as the ways in which the truth and falsehood, and validity and invalidity within that content area of chemistry (CK). A diagram was used as shown in figure 6 to show how reactant/product change per unit time by illustrating what happens during the chemical reaction and how this is represented graphical. This reflects transformation of subject matter knowledge by considering representation showing pedagogical knowledge (PK**)**. The blend of CK and PK signify the existence of PCK. The teachability of this part of rate of reaction is through technological knowledge (TK) as the teacher visualising content using a sub-microscopic description through an application MS Teams and interacting with a graph and particles shown in figure 6. Graphical and particles representations are linked to technology knowledge (TK), and this is a method devised (PK) to make content knowledge (CK) accessible to students. This indicates a complex interplay of TPACK for this lesson moment, as a result a possible misconception is prevented, which is Rate of reaction increases with decreasing concentrations of reactions (Kolomuç & Tekin, 2011). The complex interplay has allowed the teacher to show that rate of reaction decreases, as concentration of reactant decrease since reactants are forming a product.

Summary of a lesson moment below:

In facilitating the content knowledge, the teacher educator uses a PHEt simulation. The simulation is integrated to show how concentration and temperature affects thar rate of reaction. The following lesson quote is teacher educators' explanation of what is happening in the computer simulation used below. This lesson moment displays the complex interplay of TPACK, and the analysis is as follows:

***Figure 9**: The* PhET *simulation from a lesson on rates of reactions*

Below is the theory from episode 1, supporting figure 9 above.

> "*Oh well there it comes alright so for a reaction to happen there must be a collision right and collision must have the right temperature must have the right orientation the right temperature or the right energy is what you called it activation energy right so I'm gonna start this now (starting a simulation) so I've given it enough energy in the reaction A is colliding B and C forms a b + C this will happen but now if there is no longer correct orientation you find out that the they can bump into each other but there would be no reaction taking place and now this particular very very few so it will take time for them to collide and it will take time for the reaction to happen now they bound with each other it is not right orientation and there is no reaction taking place so in a reaction for every reaction to take place we need right orientation, right activation energy*".

The teacher educator uses a simulation to explain concept indicating pedagogical knowledge (PK) as the teacher use visual as means to make content accessible. Technology knowledge (TK) is integrated as simulation is used, offering visualization of content which act as a teaching strategy (PK) to engage students. Simultaneously, the component of content knowledge (CK) is reflected as the simulation is used to explain concept of rate of reaction accordingly exploring how temperature and concentration affect the rate of reaction. Figure 3 show that low concentration and without right temperature means product will be forming slowly thus low rate of reaction. It is also illustrated that even at an increase concentration if there is no right energy and right orientation the rate of reaction may continue to be slow. There is a complex interplay of Technological knowledge, pedagogical knowledge, and content knowledge for this lesson moment. A possible misconception is eliminated because of the complex interplay, which is that increasing temperature can reduce forward reaction thus increasing the reverse reaction rate (Hackling & Garnett, 1985). The teacher educator does this by using correct terminology and simulation to show students the importance of right orientation and right energy. As shown below:

> "*the rate is going very very slow so I will actually maybe the heat it up, look at the temperature it is going up and look at the bar at the average kinetic energy of the particles is going up as well right and there's a lot of collisions but they are not happening at the right orientation with the right activation energy*"

The students may have a misconception that increase in temperature increases activation energy of the reaction making a reaction faster. The correct conception would be that an increase or decrease in temperature results to an increase or decrease of kinetic energy of a reaction so that there is a greater frequency of collisions between molecules. This misconception is dealt with as the components of PCK is reflected, making knowledge easier to access and anticipating learner misconception. Moreover, the teacher shows how the effect of concentration and temperature on the reaction rate using a graphical representation anticipating learners challenges to exploit knowledge offered in graphical forms as indicated in figure 9. Simultaneously the component of technological content knowledge (**TCK**), as the teacher educator shows knowledge of the relationship between subject and technology. This is through a use of a computer simulation that is interactive to show effect of concentration and temperature on the rate of reaction to explore content area discipline. This indicates the complex interplay of TPACK.

Episode 2: The teacher educator shows competency in content knowledge.

Chemistry relies on the use of three representational levels, microscopic, macroscopic, and symbolic according to literature. Using a simulation, the teacher educator managed to show both microscopic which were reactants particles colliding in a beaker to form a product reflecting TCK component because of simulations integration. There is an interaction with TK component because to access simulations a teacher educator had to use the internet showing technological knowledge. The symbolic form which was the graph showing the amount of reactant and product during the reaction. The teacher takes a pedagogic approach of integrating three level of representation by also showing a macroscopic representation showing knowledge of using technology for effective online teaching through simulation and integrating visuals on the PowerPoint (TPK). Simultaneously, this indicate the presence of PK because a teacher is coordinating the three level of representations as a teaching strategy to consolidate understanding of factors affecting reaction rate. This is shown in figure 10 below after having shown micro and symbolic:

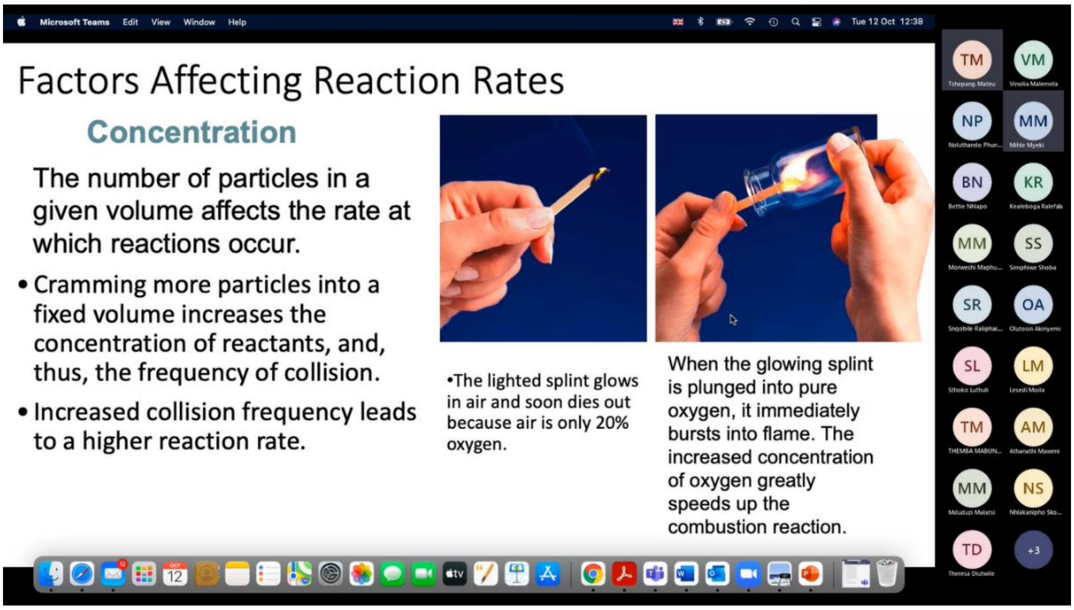

Figure 10: *The teacher educator links three representational levels in explaining factors affecting rate of reaction.*

The figure above shows how the teacher linked three representational levels in explaining factors affecting rate of reaction d how this supports the argument about the components of TPACK.

> *"OK right so you we've mentioned temperature we we we mentioned the concentration if I have also a demonstrated how concentration and temperature changes the rate of a reaction right and then particle size this would be concentration in another way right if you bend an match in the atmosphere you will find out that with time it will be dying down and you take this glowing and not glowing but Burning splint which has the little fire now because of oxygen which is little around it and put it in and glass bottle full oxygen you will find out that it rekindles and burns more why? there's more*

concentrated oxygen here more particles of oxygen than outside now and then that's a that shows you the power of concentration remember concentration is the number of moles per unit volume so if you increase them you increase the rate of a reaction if you increase temperature we are giving the particles energy the same particles with this there having more energy and they are actually maybe surpassing the activated the activated energy"

This shows strong content knowledge (**CK)** to define concentration as the number of particles in each volume. The teacher simultaneously shows **PCK** in organising the concept linking to a visual, which he anticipates that learners might think concentration and temperature affect the rate of reaction similarly as such conception may be derived from figure **8** used. Thus, the teacher educator makes a clear difference that temperature may affect the particles kinetic energy, but concentration does not. There is a complex interplay of CK, TK and PK showing evidence of TPACK at a sophisticated level.

5.2.2 Chemical equilibrium Lesson analysis

Episode 1: Equilibrium constant and Le chatelains principle teaching.

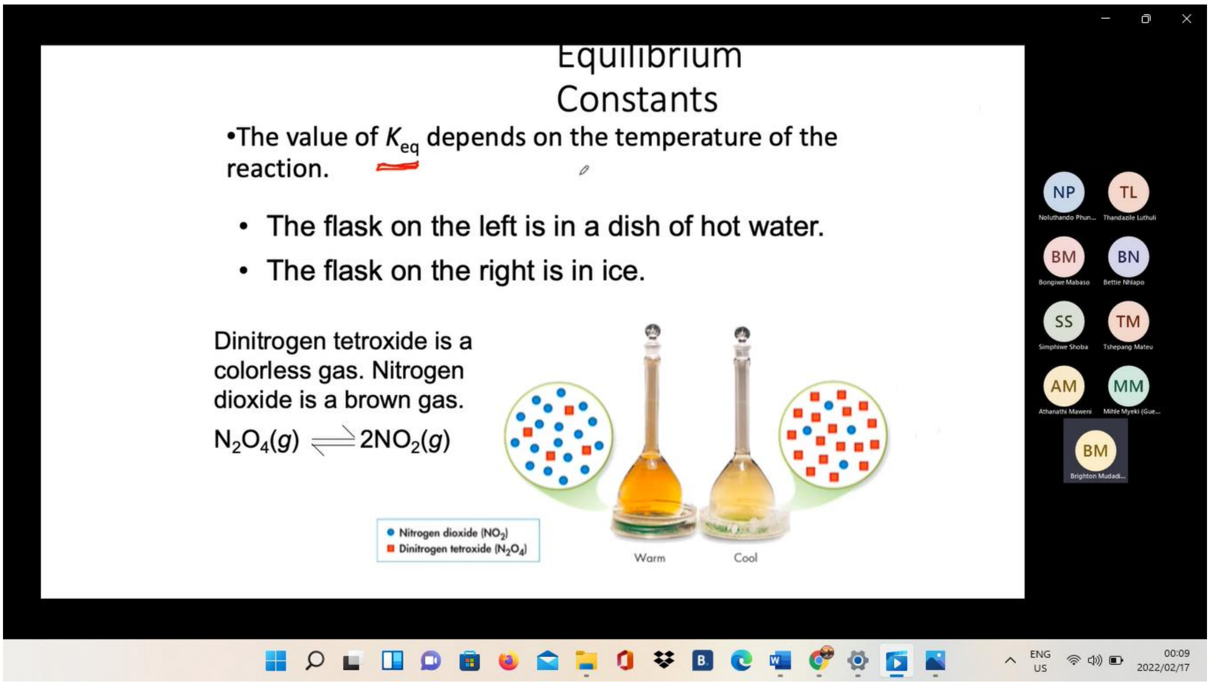

Figure 11: *Chemical equilibrium Lesson moment, illustrating factor of temperature.*

Summary of this lesson moment:

The teacher educator explains what changes the equilibrium position, discussing factors that affect rate of reaction which is temperature, concentration, partial pressure, and catalyst. The quote below is the teacher explanation of figure 11 above, where a teacher explains about temperature as a factor that affects equilibrium position, accordingly, explains Le chatelains principles in terms of what happens in a chemical reaction if concentration is added.

> "*it's only temperature which changes the equilibrium position the concentration if you look at the if you go back here and uh according to to Le chatelain principle if I add ammonia what will happen this situation is gonna react in such a way as to oppose the addition by favouring the reverse reaction which depletes the amount of ammonia that has been added*."

The lesson is taught synchronously, thus showing teacher educators competency in using technology for online curriculum delivery/to implement a teaching method reflecting TPK. The teacher educator simultaneously uses an interactive whiteboard to explain how concentration and temperature affect chemical equilibrium and equilibrium constant (TK**)**. The lecture shows (CK) in explaining the le chatelains principle that changing concentration in a reaction will result in a counter change where the reaction reacts by favouring the side with less concentration. This explanation is achieved with consideration of equations and representations as a teaching method to transform concepts of chemical equilibrium (PK), making it accessible to students. Simultaneously PCK is reflecting as a teacher educator shows by a use of a visual to teach about the effect of temperature on the equilibrium constant that it shifts/changes due to a change in temperature and indicates other factors such as partial pressure, catalyst and concentration does not change it. There is evidence of complex interplay of TPACK in this lesson moment.

Episode 2: competency in pedagogical knowledge

The teacher educator teaches the calculation of chemical equilibrium constant. This lesson moments extends from the first episode, the teacher displays the complex interplay of technological knowledge, content knowledge and pedagogical knowledge. As analysis show below:

> "*and if equilibrium is much less than one much less than one this is partially dissociating it is uh rarely forming products so it would be made, it can be a weak acid*

weak or base but it partially or a solid it partially dissociates into solution so equilibrium value actually tells us uh the extent to which the reaction will go so when K, uh when equilibrium constant has an intermediate value such as 0, 15 or 50 at the mixture will have significant amounts of both reactant and product It should be 50% right or one generally we say if equilibrium is equal to 1 right it means the concentration of the reactants are equal to the concentration of the product and uh then that's when we find equilibrium constant to be one so we need to really understand and draw information from the equilibrium position constant so it can tell us about the magnitude of I mean the magnitude of the equilibrium constant can tell us the extent can tell us the magnitude and the amount actually generally of products versus reactants right up now here we have to calculate a litter of the gas mixture at equilibrium contains this values uh right. Write the expression for the equilibrium constant and calculate the value of the constant for the reaction?"

The teacher educators evaluate students understanding by giving a calculation for concentration at chemical equilibrium reflecting **PK**. Simultaneously the lesson reflects **TPK** as the teacher uses Ms Teams to interact with students and using PowerPoint presentation in teaching the content. Content knowledge **CK** is reflected as the teacher is explain the concept of partial dissociation and equilibrium constant. Partial dissociation and equilibrium constant are taught using relevant examples and calculations, this reflects the component of **PCK** as content knowledge is emphasised with a symbolic representation of an equilibrium constant less than 1, more than 1 and equal to 1 meaning.

Relationship between rate of reaction and chemical equilibrium:

The rate of reaction and chemical equilibrium have abstract content in nature. The nature of rate of reaction is affected by factors such as temperature, concentration, catalyst, and pressure. The scale at which they affect the rate of reaction is microscopic, requiring simulations and visual representations to make this content accessible to students, similarly with chemical equilibrium. There is content progression as factors that affect rate of reaction plays an important role in describing what cause chemical equilibrium shift, what affects equilibrium position and the concepts of forward and reverse reaction. The concept of rate of reaction serves as an essential prerequisite for students to understand chemical equilibrium, thus failure to adequately explain these concepts results in misconceptions (Jusniar, Effendy, Budiasih, & Sutrisno, 2020). The lesson moments explored indicates teacher awareness of the complex interplay of technological, pedagogical, and content knowledge thus eliminating possible misconceptions.

5.3 Theme 2 Interview session

Summary of the interview session theme

The interview session establishes links between content knowledge of rate of reaction and chemical equilibrium with pedagogy applied (practical work). Accordingly, this allows the study to examine teacher educators' perspective of ICT integration and What pedagogical choices are provided for pre-service teachers to expose them to graph interpretations activities in chemistry online practical work. Links between content and practical work are then explored. The theme will include a question and a quote which indicates the answer from a teacher educator indicated as L (Lecture). A table of links between content taught and practical work is included to indicate if there is evidence of the links or not, this serves consolidate responses from the interviewee. Students interview sessions are added to understand their awareness of links between content taught, pedagogy applied and how these are empowered by ICT. Students' responses are indicated as S (Student).

L: How do you ensure that the content knowledge taught links with ICT integrated practical work for online practical session?

> "*The... the first thing which we do is, we cover the content. Uh, I'll give you an example of uh of that we did. Ugh about rates of reaction. We teach the content of rates of reaction and then we do the practical, but all this was virtual. Uh for content, I'll prepare slides which I actually presented synchronously with the students. And in an active manner following PowerPoint uh on a synchronized learning. And then after we have a booklet…a practical booklet which we follow which we have converted from face to face to synchronized online learning. and that's what...that's how we ensure that uh uh ICT is integrated in the learning and the practical is also done virtually*".

Table 4.1: Rate of reaction, links between content knowledge (CK) and Pedagogy applied (practical work)

The table 4.1 below shows the three categories, namely 1) rate of reaction concepts taught, 2) rate of reaction practical sample and 3) links found or not. The first category indicates all key concepts that were taught for rate of reaction. Second category shows the part/sample of a practical done by 4th year chemistry students after having learnt the concepts in class.

Comparisons for concepts learnt in class and what was assessed during a practical were then explored and links were found.

<table>
<tr><th>Rate of reaction concepts taught</th><th>Rate of reaction practical sample</th><th>Links found or not</th></tr>
<tr><td>

Rate of reaction
Temperature as factor affecting the rate of reaction.
Concentration as a factor affecting the rate of reaction.
Factors affecting rate of reaction

</td><td>
1. Tabulate your results by completing the table below. (4)
<table>
<tr><th>Experiment</th><th>Temperature of the mixture in the flask/°C</th><th>Time taken for the cross to disappear /s</th><th>1/time Taken/s-1</th></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
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</table>
2. For each set of results calculate the value of 1/time. (2)
3. Plot a graph of 1/time on the vertical axis and the temperature on the horizontal (x) axis. (5)
4. Deduce the relationship between rate of reaction and temperature. (1)
5. Explain how an increase in temperature affect the rate of a reaction? In your explaination, giving two reasons in terms of Collision Theory. (4)
6. Indicate the effect of change upon the rate of reaction when the temperature is doubled. (3)
7. Calculate the concentration of 40g of Sodium thiosulphate in 250 ml of distilled water. (4)
</td><td>Links were found.</td></tr>
</table>

Table 4.2 Chemical equilibrium, links between content knowledge (CK) and Pedagogy applied (practical work).

The table 4.2 below shows the three categories, namely 1) Chemical equilibrium concepts taught, 2) Chemical equilibrium practical sample and 3) links found or not. The first category indicates all key concepts that were taught chemical equilibrium. Second category shows the part/sample of a practical done by 4th year chemistry students after having learnt the concepts in class. Comparisons for concepts learnt in class and what was assessed during a practical were then explored and links were found.

Chemical equilibrium concepts taught	Chemical equilibrium practical sample	Links found or not
- Equilibrium constant - Le chatelains principle - Finding concentration at equilibrium	Watch the video uploaded on SAKAI. The video was prepared to demonstrate the effect of temperature on chemical equilibrium, and this is the emphasis given in the demo. Our specific focus is the implication of the observations for understanding the energy changes when a chemical bond breaks and forms. Having watched the video, please answer the questions below. **Questions** **Q1**. Compare the colours of the hot and cold gas sample. Which of the following is your observation? A. The hot gas is dark brown and the cold gas is almost colorless. B. The cold gas is dark brown and the hot gas is almost colorless. **Q2**. Taking into account that NO_2 molecules are dark brown and N_2O_4 molecules are colorless, which molecules must have the lower energy? A. N_2O_4 B. NO_2 **Q3**. What is your reason for your choice in Q2? A. They predominate at lower temperature. B. They predominate at higher temperature. **Q4**. Which direction of reaction is exothermic? How does the experiment show this? A. $2NO_2 \rightarrow N_2O_4$ is exothermic because there is more N_2O_4 in the hot gas. B. $N_2O_4 \rightarrow 2NO_2$ is exothermic because there is more NO_2 in the cold gas. C. $2NO_2 \rightarrow N_2O_4$ is exothermic because there is more N_2O_4 in the cold gas. D. $N_2O_4 \rightarrow 2NO_2$ is exothermic because there is more NO_2 in the hot gas. **Q5**. When a chemical bond is broken, is energy released or absorbed? A. Absorbed. B. Released. **Q6.** Consider the reaction the following reaction at 14 °C at a particular time. $N_2O_4\ (g)\ \ 2NO_2\ (g),\ K_c = 0.2.$ After the reaction was suddenly cooled and analyzed, it was found to have the following concentrations $[N_2O_4] = 2.0\ M,\ [NO_2] = 0.2\ M.$ Determine if this reaction is at equilibrium and the direction will the reaction proceed?	Links were found

There are links between the content taught and the ICT integrated practical. The study then examines if the students are aware of these links and how they make their understanding of the relationship explored (graphically the independent and dependent variables) explored during online practical work. Below is the question and answer of students:

S: How does links between content knowledge taught and ICT integrated practical makes it easier for you to understand the relationship explored during online practical work?

> "*Mr Sir: Yes it makes it easier for for me to conduct the practical with some concept that I know for example when I'm being taught a certain content I will know what reactants are to be used or let me say what material is to be used to conduct that practical and then what am I expecting to be formed during that practical that means now the product that is to be formed there it gives me a better direction of what needs to be done actually so knowing the content before a practical it makes things easier*"

> "*Mr Skhosi: uh-yes. I believe so, yes because…eh…theory is one thing and I think when I look at it, I think that theory is during that content. During that time when they are teaching us content. So, it's sort of like theory. But when it comes to practically then turn to use or whatever information that was taught to us uhm and then apply it in practice, during that practical work. So, we get to see it happening or not happening accurately and then whatever the case may be but I think it makes it better to understand during practical, yes*"

> "*Grace: Yeah, it certainly makes it easier because uhm sometimes uhm you go through their experiment having like uhm the, not necessarily the exact results but knowing exactly like the direction towards uhm, the direction in which you supposed to be going. So, It also helps us to, how can I put this, to to spot even maybe if there are irregularities nyana there they really do help us so I think the pre, pre knowledge does help in these practical's a lot*."

100% percent of students interviewed are in agreement that links between content taught and practical work are useful to understand the practical work and accordingly the relationship to be explored in that practical work. Some of the direct quotes from the students are shown above.

5.4 Theme 3: Empowering chemistry practical work through ICT integration

Summary of Theme 3

It explores how ICT empowers chemistry practical work and accordingly how this affect students in terms of graphs. ICT integrated practical work may mean students have to use ICT tools to plot graphs and to conduct practical work therefore their readiness is explored. This theme has questions and answer from the interviews where a teacher educator is represented by L (Lecture) and students/participants are represented by S (students). The practical video sample is used to consolidate points made by a teacher educator.

L: How do you use ICT tools such as computer simulation, modelling tools, and video analysis tools to empower practical work to provide students with practical and graphing skills?

The teacher educator shares how practical work was designed and prepared. The practical was conducted virtual using e-learning canvas, in a form a video practical that was recorded in a lab. The video practical may be considered ICT integrated as the videos are multimedia thus ICT.

> "Lecture: Uh we did rates of reaction we myself and the team went into the lab and we conducted the experiment on the uh precipitation of sulfur, uh where the change or the independent was the temperature. The variable… the independent variable was the temperature. So, we set out water bath from 20 degree. 10 degrees, 20 degrees until 60 degrees in a water bath and we were taking videos"

The videos were reduced in number of minutes and the readings were included in the video along with variables, students had to record data and answer questions as the teacher educator indicates "*The readings...eh the variables which were there, the measurements which were there which we took and then they will answer the questions and fill the table. And after filling the table they were graphs which they were supposed to write and then they send the answers online after watching those videos*". Below is evidence supporting the teacher educator about making results and variables accessible to students. This may be indicating an advantage of ICT integrated practical work as it data presentation is clear to students thus alleviating challenges of representing scientific relationships using graphs. A student mention that:

> Mr Chakalaka: "*it's not going to a challenge if if if if the data is present and if the data is clear. I think that that's that's that would be a a shortcoming when comes to graphs however, if the data is clear and well-presented then of course there are no challenges*."

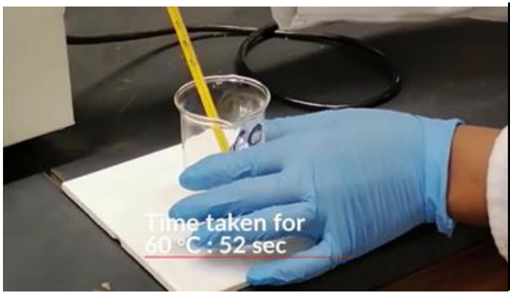


Figure 12: *Data presentation as extracted from the rate of reaction practical.*

The students access this practical on World Wide Web site which is another form of ICT. The practical is empowered through a use of videos to allow students to have a first-hand experience of a phenomena and observing manipulation of apparatus done in real life. It was expected of them to undergo video analysis to answer practical questions. The teacher educator acknowledges that such practical offers manipulation and observational skills. Moreover, students can acquire data recording and graphing skills. However, a lecture mentioned limitation which is that students do not have hands on experience as the practical is done virtual as shown below:

> "*So, they are observing everything. And then the other skill is for recording, which they are doing on their own and then the third skill now it will be graphical. And the fourth skill now it will be analysis. You have to analyze uh uh uh uh by answering questions. Uhm so my believe is that Chinese proverb which says uh "I see and I remember. I do and I understand. I hear and I forget" so we didn't do it in virtual, we didn't do the I do. But we did the other two which is I see and I remember. So, they were seeing the manipulation of apparatus by my assistants who were doing this practical. So, with this when they are not faced uh with real like situation in the classroom. There were fourth years, next year they will be in classrooms teaching they will remember how the apparatus were manipulated*"

This shows that the chemistry practical work is not aimlessly conducted but there is a purpose which is for acquisition of skills and measuring chemistry theory.

S: How easy is it to use ICT tools such as Excel to plot and interpret chemistry graphs?

Students show differences when it comes use of ICT tools such as Excel and it has to do with their competency in using technology and preference. Literature shows spreadsheets particularly excel may complement practical work as it gives computer generated graphs (Denby & Holman, 2002). Students benefit from computer generated graphs as it allows them to critically look at data, students may quickly notice the experimental variables changes as they load data (Denby & Holman, 2002). Students may be able to easily draw graphs with hand with the help of computer-generated graphs (Denby & Holman, 2002). Students often do not rely on the ICT tools due to reasons of competency and preference thus are not able to exploit advantages that comes with using spreadsheets to help with graphical challenges.

Category 1 student indicate that there are struggles in using Excel such “Mr M: *there's some there some struggles there that you have there are some things that you have to do there like adjusting your points sometimes the the scale so yeah I can say that's its a bit trickey its not as easy as using hands yeah*”. This shows that he prefers drawing graphs manually sing hands than using ICT tool such as Excel and it has to do with competency in using the tool.

Category 2 student shows that understanding how the tool works is important “*Mr Chacalaka: to be honest, it's quite tricky especially if you don’t have ICT background or you don’t have Microsoft background for ICT. I mean for for excel. it becomes very difficult. so even I personally have a challenge of using excel and understanding how excel works when plotting the graph*.”. The inability to comprehend the use of tool means difficulties in realising its benefits. Another concedes the difficulties in using Excel “Mr Skhosi: *I’m not or excel is not one of my abilities or yah it’s not something that I do well in. Excel for example. So, I’m maybe I could do better using word. I don’t even know which commands to punch or which tabs to look for in terms of going to plot a perfect graph on excel. So, it’s not always easy.*”. Using excel is not easy but word is preferred to do the same activity.

Category 3 student shows competency in using Excel and proves to be knowledgeable as he mentions “Mr Sir: it it it is very easy because you just if you have your values, you just go you insert the table there and then you insert the values that you are given there. Eh you identify the independent and the dependent in terms of X & Y axis and then you just put in the values there the graph will be plotted”. This may mean such students are able to experience benefits that are brought by a use of Excel. This means ICT tools may set students apart as those that are competency benefits from the tool and the incompetent students does not.

5.5 Theme 4: Evaluating students’ understanding of chemistry graphs.

Summary of Theme 3:

Theme 3 is about evaluating students’ understanding of chemistry graphs. This suggests examining lectures perspective of how students are evaluated, making reference to the practical done. Practical conducted is ICT integrated and this alludes to explore students’ perspective of this type of practical, accordingly evaluate this using activity theory. This study explored two lessons for topic of rate of reaction and chemical equilibrium. ICT integration in practical work was possible for both these lesson topics, therefore this presents a series of connected events 1) evaluating students understanding of chemistry graphs from ICT integrated practical work, 2) Perspective of students on ICT integrated practical work. ICT integrated practical document is then analyzed by this study to understand the usefulness of ICT integration on practical work in interpreting experimental data using graphical representation. Theme 3 is then separated into four sections namely, 1) Teacher educators input on 4th year chemistry students evaluation of ICT integrated chemistry practical, 2) Understanding students' perspective of ICT integrated practical work and its evaluation through activity theory, 3) Rate of reaction practical ICT integrated practical, 4) Chemical equilibrium ICT integrated practical, then under chemical equilibrium ICT integrated practical these sub-themes are explored sub-theme 1) Category 1: Lower scorer chemical equilibrium graphical interpretations, sub-theme 2) Category 2: middle scorer chemical equilibrium graphical interpretations. Sub-theme 3) Category 3: Higher scorer chemical equilibrium graphical interpretations

5.5.1 Teacher educators' input on 4th year chemistry students' evaluation of ICT integrated practical for rate of reaction and chemical equilibrium.

L: How do you evaluate students understanding and ability to apply scientific knowledge using graphical representation?

The teacher educator indicates that students understanding and ability to apply scientific knowledge using graphical representation is through marking the post lab practical looking at the students graphs and their answers. This shows if theory taught, and the practical conducted were meaningful to students or not:

> "*Lecture: Right. Uh I will retardate their answers in the post lab. Uh uh uh, right? Actually, they were asked to uh write and answer the questions which were directing them to the skills which we were looking for and we would look at the graphs and their answers that would actually give us an idea if theory and practical works has actually been meaningful. And or learned meaningful with these group of learners*."

5.5.2 Understanding students' perspective of ICT integrated practical work and its evaluation through activity theory:

The practical is done virtually and is ICT integrated which this reflects the tool/artefact component of activity theory. ICT integration in chemistry practical work is considered with a purpose of empowering practical work which is an object, a second component of activity theory. This is done to make the practical accessible and to ensure students acquire practical skills and graphing skills for students who are subjects (subject is the third component of the activity theory). The theory and practical work dealt with in this study resemble science community particularly chemistry (community is the fourth component of the activity theory). Understand and interpreting graphs requires students and teacher educators to understand the rules of chemistry graphs, and rules is a 5th component of activity theory. Lastly, conducting practical work means students must be taught theory of chemistry by a teacher educator/lecture and receive assistance from the university chemistry tutoring systems (TA's), this introduces the last component which is the division of labour as teacher educators and tutors share responsibility of teaching.

The division of labour is between teacher educators and chemistry tutors. Content taught for rate of reaction shows complex interaction of TPACK components, showing that the lecture is aware of the interplay of TK, CK and PK which comes about a choice of teacher educators' choice of pedagogic approach. The lecture indicates that tutors are trained and are available to assist students with the theory and the practical work.

> *"They were put in four groups for tutorials with two tutors. Per group and they would give each other time. That this tutorial is from this time to that time. It was maybe for 45 minutes to an hour. That's when students now would be asking questions and uh being helped by the tutor"*

Literature shows that students' proper interpretations and comprehension of the relationship between chemistry concepts, conceptual understanding is directly linked to students' successful interpretations and understanding of graphs (Seçken & Yörük, 2012). Graphs are used in a science classroom and laboratories as they present knowledge that most datasets cannot present solely (Gultepe, 2016). Graphs in this case graphs are part of the object which is practical work to measure students' understandings of concepts taught and if they have acquired intended skills including practical and graphing skills. Lack of skills is one of the reason students are experiencing difficulties in graph interpretations in science, including drawing these graphs (Glazer, 2011). Literature shows that the difficulties experienced by learners are firstly, lack of knowledge about rules and language of graphs, secondly its inadequacy in contextually comprehending concepts, thirdly it is problems related to defining variables presented and linking graphs with these variables, and lastly it is prior knowledge of a graphs content (Gultepe, 2016).

The way rate of reaction is taught shows sophisticated level of TPACK, and during the lesson students were exposed to graphical rules and language in a form of rate of reaction visuals and simulations. Moreover, students were shown graphs of concentrations and temperature thus were familiarised with identifying variables when dealing with such graphs. This shows that when teaching chemistry, rules of how things are done in a sphere of chemistry are taught as part of learning chemistry theory. This occurs because there is a division of labour where lectures and tutors share the teaching responsibility. This prepares students (subjects) for the chemistry practical works (Object), and accordingly the object is conducted online and is ICT integrated (tool) thus ICT is responsible for transformation, making it easier for students to experience the phenomena and how apparatus are manipulated in a real world. ICT integrated practical has shown to improve graphing skills according to literature. Below is the evaluation from graphical related questions.

The most graphical challenges were dealt with prior to the practical work. Students related questions mostly showed correct understanding from students:

5.5.3 Rate of reaction practical evaluation:

The analysis will show the highest scorer, middle-scorer and lower scorer. The highest scorer Grace who is category 3 considered using ICT tools as time wasting and preferred drawing a graph using a hand. Grace got maximum marks on graph related questions, she was able explain the relationship between time and temperature as represented in a graph. Moreover, she was able to account how increase in temperature affects the rate of reaction in terms of collision theory. Grace sample of work is shown below:

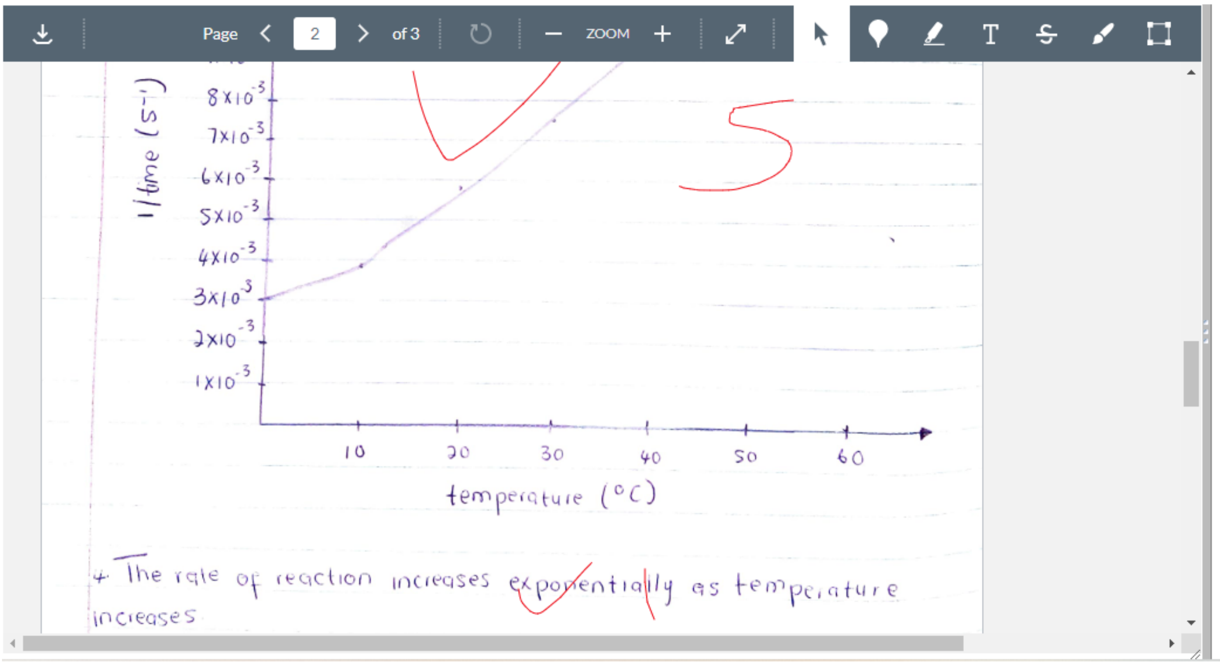
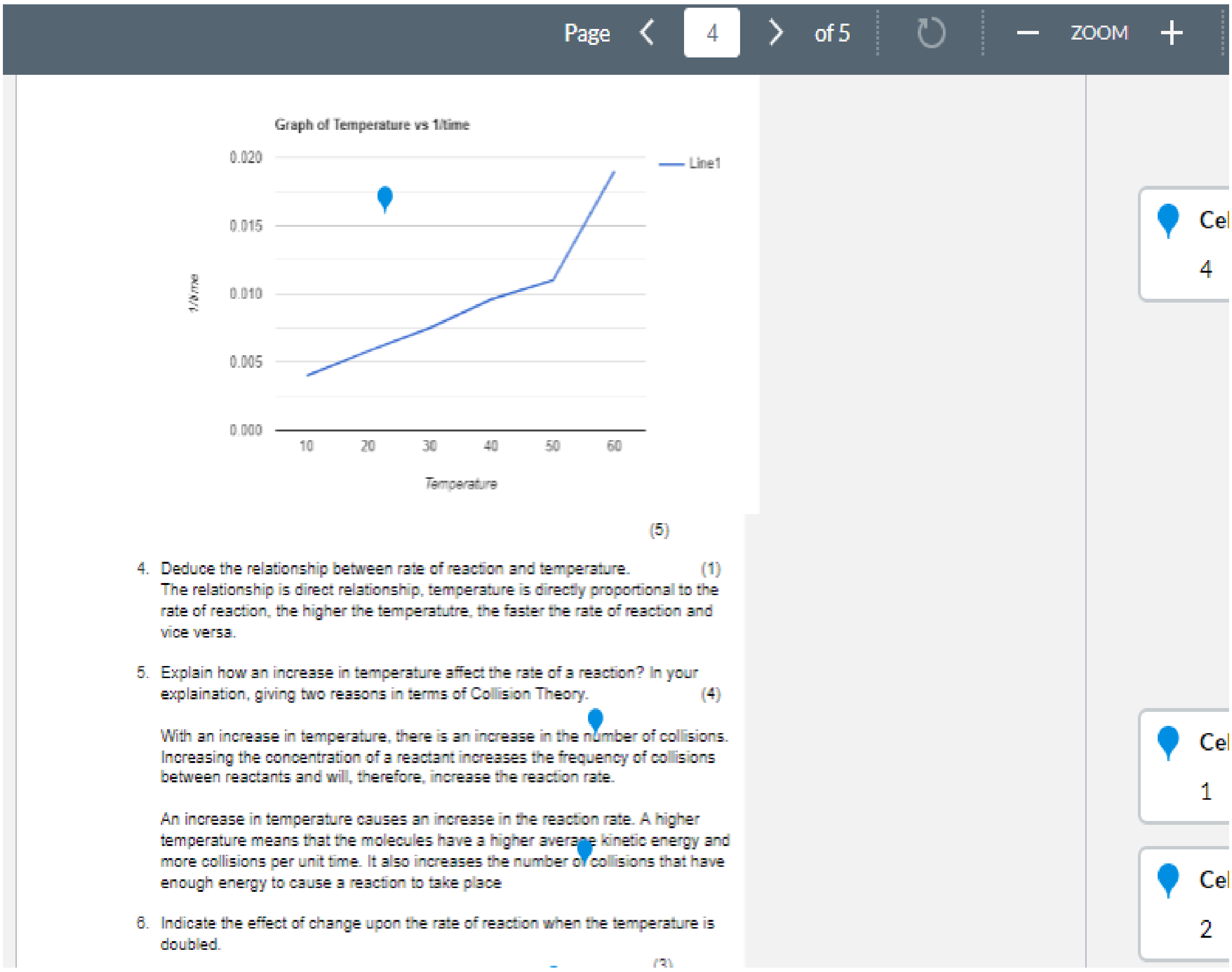


Figure 13: *Scores for Rate of reaction practical for Grace*

Mr Chakalaka who is category 2 a middles scorer, indicated the personal challenge of using excel and that as an option he uses words which does not produce precise graphs:

> "*I personally have a challenge of using excel and understanding how excel works when plotting the graph. usually, I opt for word because it's easier however it's not precise or accurate*."

The graph produced was missing a line of best fit and a bit of precision. Mr Chakalaka lost a mark for the graph but was able to interpret the relationship represented in a graph. Another mark was lost on accounting for how increasing temperature affects rate of reaction in terms of Collison theory. A sample of work for Mr Chakalaka is shown below:



(5)

4. Deduce the relationship between rate of reaction and temperature. (1)
The relationship is direct relationship, temperature is directly proportional to the rate of reaction, the higher the temperatutre, the faster the rate of reaction and vice versa.

5. Explain how an increase in temperature affect the rate of a reaction? In your explaination, giving two reasons in terms of Collision Theory. (4)

With an increase in temperature, there is an increase in the number of collisions. Increasing the concentration of a reactant increases the frequency of collisions between reactants and will, therefore, increase the reaction rate.

An increase in temperature causes an increase in the reaction rate. A higher temperature means that the molecules have a higher average kinetic energy and more collisions per unit time. It also increases the number of collisions that have enough energy to cause a reaction to take place

6. Indicate the effect of change upon the rate of reaction when the temperature is doubled.

Figure 14: *S*cores for Rate of reaction practical for Mr Chakalaka

Mr M is category 1 a lower scorer amongst the interviewed students but in graphical related questions he lost a mark for not writing a title of a graph but got maximum points for all other graph related questions. A sample of Mr M is shown below:

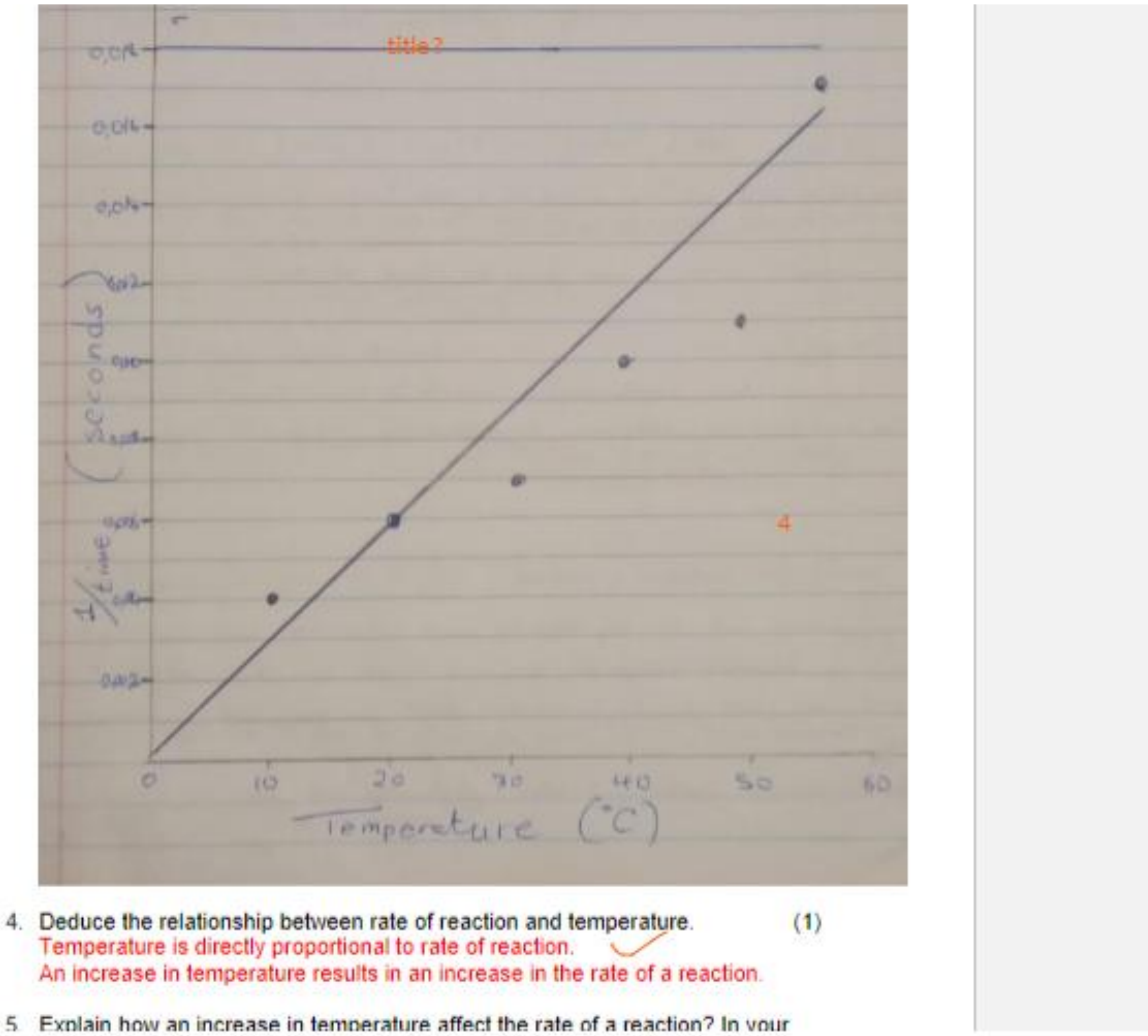


Figure 15: *S*cores for Rate of reaction practical for Mr M

5.5.4 Chemical equilibrium ICT integrated practical evaluation:

Summary of chemical equilibrium ICT integrated practical evaluation:

The chemical equilibrium ICT integrated practical did not have graphical related questions. The students' participants were then asked to interpret the chemical equilibrium graph during the online interview after having been taught content and conducted chemical equilibrium online practical. The responses from the participants were recorded from the interview. The students' responses are then recorded below and analysed to understand their ability to interpret chemical equilibrium graphs given they have been exposed to content knowledge. A simulation was not provided to learners to assist with the interpretation as the purpose was to observe their ability in the absence of ICT usage. Comparisons of this evaluation are later to be compared with rate of reaction since rate of reaction was ICT integrated and had a computer simulation. Responses based on chemical equilibrium indicates a common misconception for all students except one. The misconception is that chemical equilibrium is reached at the end of the plateau in a graph. The correct conception is that as the plateau begins the equilibrium is reached since the plateau shows that the rate of forward reaction and reverse are equal. Figure 16 below shows the graph of chemical equilibrium that was analysed by students.

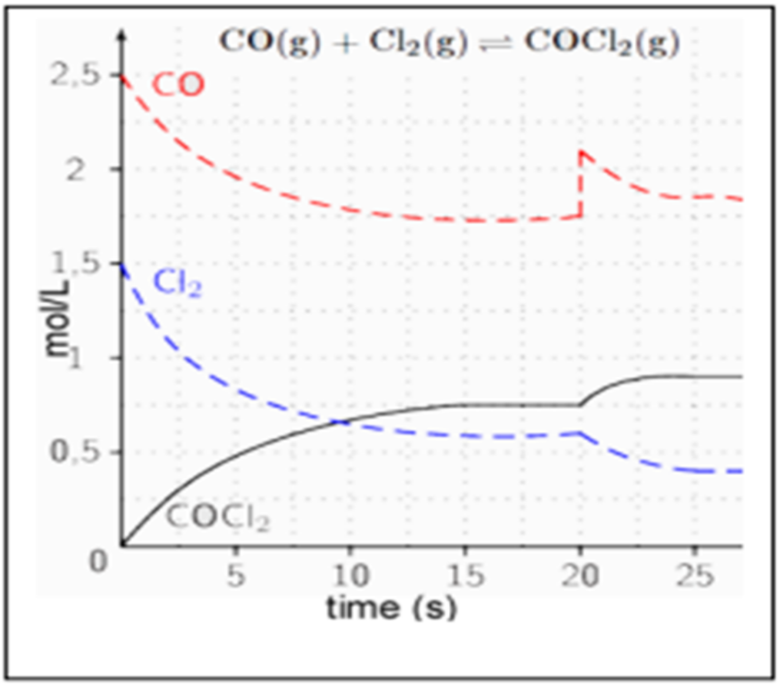


Figure 16: *Chemical Equilibrium graph*

(i) Category 1: Lower scorer chemical equilibrium graphical interpretations

Student indicated a misconception when attempting to interpret the chemical equilibrium graph above. How long does this reaction take to reach equilibrium? Mr M showed a misconception as he chose 20s "*Mr M: Oh, for the reaction to reach, let me see I can say its 20 minutes*". The correct conception is that the reaction reaches equilibrium at 15 second mark. A follow up questions was asked to check if the student will correct his conception, what happened at the 15 second mark? The student could not realise a fault in his initial conception thus maintained it "*Mr M: Oh, I can say let's say I'm not sure, but I can think that's a transition state that's where now the reactants are forming the products before the equilibrium is being reached*". Additionally, a question was asked as an attempt to evaluate if they will realise what chemical equilibrium means. A question is how the rates of the forward and backward reactions changed from 15 – 20s. The student acknowledged that "he rates now there were I can say they were equal because they were reaching equilibrium, so they were equal, flowing at the same rate". This is correct but the student did not realise how the conception of a reaction reaching equilibrium at 20 second is incorrect. Developing the understanding of chemical equilibrium was then asked what happened at 20s mark. Mr m could not comprehend that CO2 was added in the reaction but held on to a conception that

> "*Mr M: Mmh the 20 second mark, I can say that's when they are reaching equilibrium, I guess*."

This supports literature that students require conceptual understanding, rules and language of chemistry graphs. The student indicates lack of conceptual understanding that chemical equilibrium is reached at the beginning of a plateau/when the rate of the forward is equal to rate of reverse reaction. Category 1 student was then asked to interpret how the system responded to a change that occurred in the graph. He adds that "*Mr M: So, I could say the products were being formed now, it was balancing the equation or the reaction so the products can balance with the reactants*". This a correct interpretation.

(ii) Category 2: middle scorer chemical equilibrium graphical interpretations

The students show a misconception about when equilibrium is reached. Both students at this category share this misconception.

> "*Tshepo: Uhm, it takes 20seconds*."

> "*Mr Chacalaka: No, I'm confident with 20* "

The misconception affects how the students answer the rest of the questions related to the chemical equilibrium graphs. When category 2 students were asked about what happened at the 15 second mark, they mentioned that:

> "*Mr Chacalaka: uh OK now it gets tricky, but I think that's where equilibrium is initiated"*

This is a correct conception as when the rate of a forward and reverse reaction rates are equal then equilibrium is reached.

> "*Tshepo: What happened? The reaction was still proceeding. That's what I see*."

He maintains the incorrect conception about equilibrium being reached at 20 seconds thus unable to observe what happens at 15 seconds mark. When a follow question about the rate of forward and reverse reaction from 15 – 20seconds.

> "Mr Chacalaka: um so the forward reaction I think is equal to the reverse reaction, hence both reaching equilibrium."

> "Tshepo: They are starting to occur at the same rate."

Mr chakalaka manages to rectify his conception about equilibrium being reached at 20seconds. And Mr Tshepo manages to acknowledge that they are occurring at the same rate. When questioned about what happens at 20s the category 2 student mention, "*Mr Tshepo: the formation of products was equal to the formation of the reactants*". Unable to interpret a change in a graph, lacking understanding of chemistry graph rules and language. The second student notices a change but cannot explain what has changed even though it is shown in a graph through a CO graph line.

> "*Mr Chacalaka: There was a change. I'm not sure change in what changing the reaction or change in in equilibrium I'm not sure but there was a change. There was a change maybe a catalyst was added, I don't know. But there was a change*"

Mr chakalaka was able to observe that there was a change but could only guess. Category 2 students were thus questioned in terms of how the system responded to the change. They both showed a correct conception.

> "*Tshepo: As that concentration is consumed. The products COCl2 then is also increased again. So that it will go back to equilibrium*."

> "*Mr Chacalaka: Um … I think the system continues to reach equilibrium furthermore.*"

(iii) Category 3 Higher scorer chemical equilibrium graphical interpretations.

Category 3 students were asked to extract information from the graph about when equilibrium is reached. One showed a correct conception," Mr *sir: let me see could you please zoom it in again I can say it takes 15 seconds*." And another showed an incorrect conception. She added that "*Grace: Mmm okay, I think its 20 minutes*.". Follow up questions were made to help students question their responses. What happened at the 15s mark? Was the question posed. Mr Sir maintained a correct conception and indicated "*Mr Sir: OK OK the the the, let me say the reaction was in equilibrium*". Grace also showed a correct conception "*Grace: Mm the rate* *of reaction…. Okay can I just try and analyse it for a minute. Yeah, the concentration of products and reactants uhm stop increasing or decreasing they just remaining constant*.". When asked about the rate of forward and reverse reaction at a range of 15-20seconds Mr Sir could not answer as he claimed the question to be a difficult one "Mr Sir: this is a tough one!". Mr sir is a high scorer but could not answer the most answered correct question, and this can be linked to lack of exposure to chemical equilibrium graph concepts/lack of clarity from the question. Grace was able to identify that "*Grace: Mmmh it remains constant*". When asked about a change occurring at a 20 second mark, Mr sir proved knowledgeable as he was able to interpret the graph "*Mr Sir: I can say there was an addition of the CO reactant there in the reaction and then we can see the chlorine reactant becoming less and then the CO becoming more there at that 20 second mark. Then more products were formed also, the concentration was increased there, that's what I can say, of CO*". However, Grace failed to arrive at a correct interpretation. She mentions:

> "*Grace: 20 second mark, uhm yoh there was a drastic change, there was a drastic change for the COCl2 the product. Uhm yoh the rate of reaction increased rapidly, yeah, a rapid increase in the rate of reaction*".

The correct conception is CO was added in the reaction/system. When asked about how the system responded to the change. They both showed a correct conception.

> "*Grace: Oh, okay the system react in such a way to counteract the change*."

> "*Mr Sir: It responds by giving us more more products or the concentration of the product was increased there. That's how it responded to what happened there at the 20 second mark.*"

Prior to the practical work student, during the lecture lesson for chemical equilibrium, le chatelains principle was explain using an example of adding a concentration of ammonia in a reaction but the visual was not used. Most of the participants could not understand how a graph would look like if a reactant/product is added or increased in concentration. They understand there was a change but, they do not know what caused the change. The teacher educator relied on students' prior knowledge as they have done chemical equilibrium in FET and early years of undergraduate. This may be linked to poor graphical comprehension that exists across categories. The teacher educator mentions that:

"*Lecture: In each grade at FET phase, it actually emphasizes the graphical uh uh uh analysis and I mean skills learning of the students. So, at higher institution, the students should be now knowing and should be applying that. Maybe they would do it in first year just to remind and check if there are no misconceptions which I mean at a school level but at fourth year level in university applications is the utter most importance to us*"

However not revisiting chemical equilibrium graphs, and their rules shows that student may continue with lack of graphical understanding if their prior knowledge remain unchecked. This does not affect lower scorers but middle and higher scorers too. It is then essential for students to be diagnose about chemistry graph related content to identify possible misconceptions from students' prior knowledge as some students may not be aware that they have misconceptions. Lack of awareness means although tutoring support system is available students may not receive assistance because they will not report they have problems since they are not aware.

5.6 Theme 5: Usefulness of ICT integration in chemistry practical work graphical interpretations.

L: How do you measure the effectiveness of ICT integrated practical work in achieving objectives of attaining practical skills in practical work session?

What students produces indicates whether ICT integration was successful or not, as chemistry teacher educators rely on the student's practical work/submitted work to examine their responses and how they answer questions. Thus, allowing the teacher educators to gauge on the effectiveness of ICT integration. Below the teacher educator mentions:

"*Lecture: One, uh did they actually give us the correct readings? Did they record the correct readings? And if they are correct, uh did they draw a proper graph? And did they answer the questions? So, if they did it properly according to the theory they have learned synchronously and the results were fruitful, we got a lot of students doing very well. That's actually gave us the idea that if one has a gone through the videos and was able to answer those questions successfully and uh uh meaningfully and engaging very well, giving us a vivid and clear explanations with the rigor of the subject uh matter, then we were satisfied that uh the ICT was effective*."

Usefulness of ICT integration extends to affordances/benefits towards students during online practical work. S: Can you easily identify the independent, dependent, and controlled variables while observing ICT integrated practical work?

Category 1 student indicate that it dependents on how the data is presented during the online practical work, as he states "*Mr M: I think if there is a graph or a table you can easily identify like we had a graph there, so it was easier to identify the independent and the dependent variable*.". Category 2 students show differences as one acknowledges that since it is a visual it is useful in understanding data and identifying the variables, as he shares "*Mr Chacalaka: so, since there was a visual representation and the demonstration. It was easy for me to identify the independent and dependent. Unlike when I was given just a table and I was told to plot and and create a graph*". The second category 2 student remains undecisive but mostly acknowledging that it is not easy to identify variables on the ICT integrated chemistry practical work. This is because, he considers that topics are different thus identifying variables to certain topics may be easier compared to others.

> "*Tshepo: no. Actually no. I can't. I cannot easily identify those. it usually takes me time and uhm, I need a detailed analysis before I can determine, and it doesn't often come easy. It also sometimes depends on what we are working with. So, with other things or with other topics it's not so easy. And with some other topics it is easy to say this is the one that is the dependent and this is the one that is the independent and so forth*."

This shows that ICT integration may not be the answer solely as aspect of conceptual understanding need to be addressed prior to the practical activity. This may ensure that student find content/topic easier thus able to identify variables.

Category 3 student concedes that it is easier to certain extent, "*Grace: Yeah, I think it's easy to identify independent and dependent variables, with the controlled I I think you need you really need to have you know those basics first*". The second students remain undecisive as he shares that it "*Mr Sir: It depends on the information that is given there*".

S: How does observing ICT integrated practical while plotting a graph affect your abilities to? use the table below?

A simulation was shown to students. The simulation acted as a snippet to show students a phenomenon while a graph is forming/plotted. The simulation was showing a mini experiment representing an ICT integrated practical work was observed online athttps://javalab.org/en/category/chemistry_en/chemical_reaction_en/. The graph was concentration-time graph which students were expected to interpret:

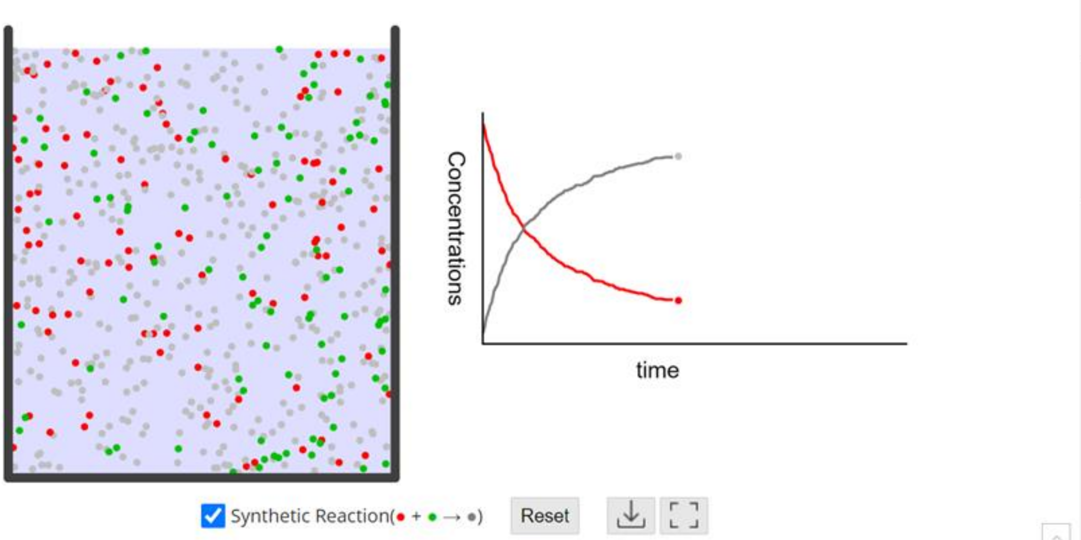


Figure 17. *Illustrating a mini-experiment simulation*

Below were the results from 4th year chemistry students graph interpretations.

Table 5: Interpretation of the graph

Table 5 below present's data collected from the interview about 4th year students' perspective of ICT integration making their interpretation easier or not. How does observing ICT integrated practical while plotting a graph affect your abilities to: A template was provided with categories 1) analyses graph, 2) describe graphs, 3) construct graphs. 4) Compare graphs, 5) Interpret graphs. The findings are recorded below per students' responses. All participants agree that ICT makes it easier to interpret and compare graphs, 1 participant claim it makes it difficult to construct graphs, 1 other participant says it makes it difficult to describe graphs. 1 other participant claim it has no effect on analysing a graph.

Table 5: Data collected from the interview

	Makes it easier to	**It has no effect**	**It makes it difficult to**
Analyse graphs	All participants except one, agree that it makes it easier.	1 participant indicated that it has no effect	
Describe graphs	All participants except one, agree that it makes it easier.		1 participant indicated that it makes it difficult
Construct graphs	All participants except one, agree that it makes it easier.		1 participant indicated that it makes it difficult
Compare graphs	All participants agree that it makes it easier		
Interpret graphs	All participants agree that it makes it easier.		

Figure 18 below shows the graphical representation of the data in table 5 above. The graph shows statistically the perspective of ICT integrated practical impact on their ability to make sense of experimental data graphical. This indicates a high statistically significant high students in interpreting and comparing graphs categories, indicating the impact of ICT integration on chemistry practical work for graphical related questions. However, although all participants acknowledge the impact of ICT in comparing and interpreting graphs, some participants concede that ICT may not have an effect in analysing. Analysing was a concern for students as recorded from interview, students believe that although ICT is useful but basics about graphs is of great importance for students to interpret graphs. Graphical construction is also a concern as students who are not competence in ICT tools such as Excel and word to plot graphs struggles and as a result lose marks. One participant claim that ICT makes it difficult to describe graphs, but all other participants believe it makes it easier.

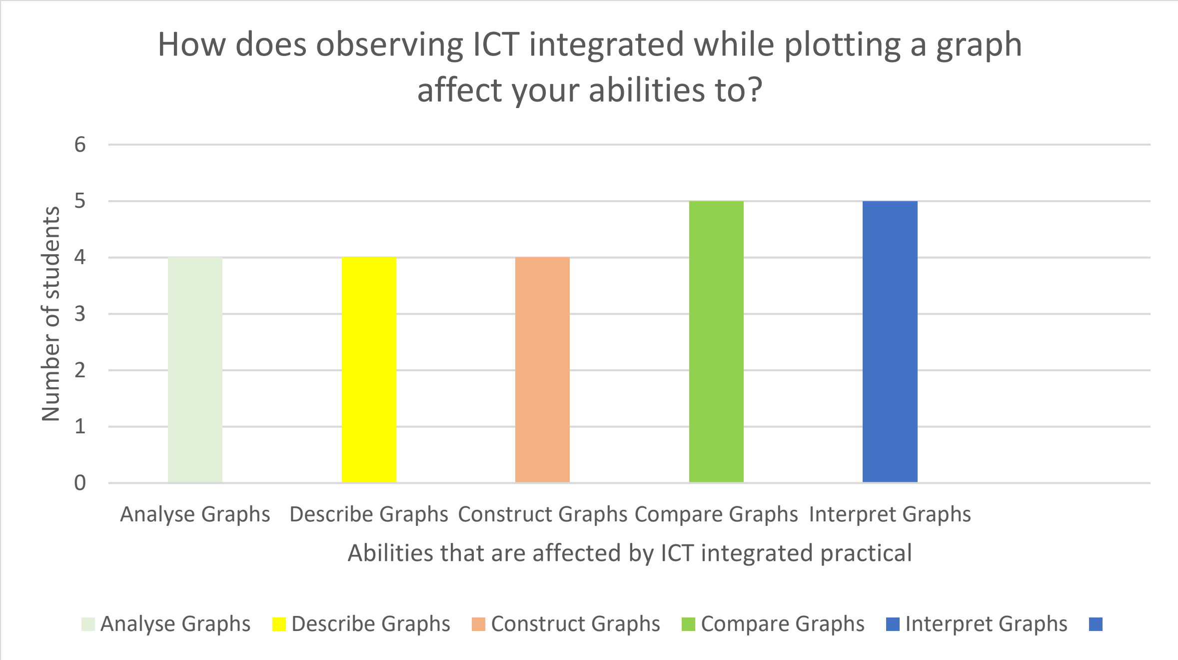


Figure 18: *Graph for ICT integration in chemistry practical work results for 5 students' participants*

Theme 6: The summary of both lesson and the complex interaction of TPACK in each lesson mind map

Summary of Theme 6

Theme 6 displays a diagram representation of the two lesson topics explored. Figure 19 shows the diagram for rate of reaction indicating how concepts were taught and how this informs the practical, ICT empowers content taught and practical therefore this allows a study to explore the outcomes in terms of students understanding of chemistry graph. Figure 20 shows a diagram for chemical equilibrium and it follows a similar pattern to rate of reaction.

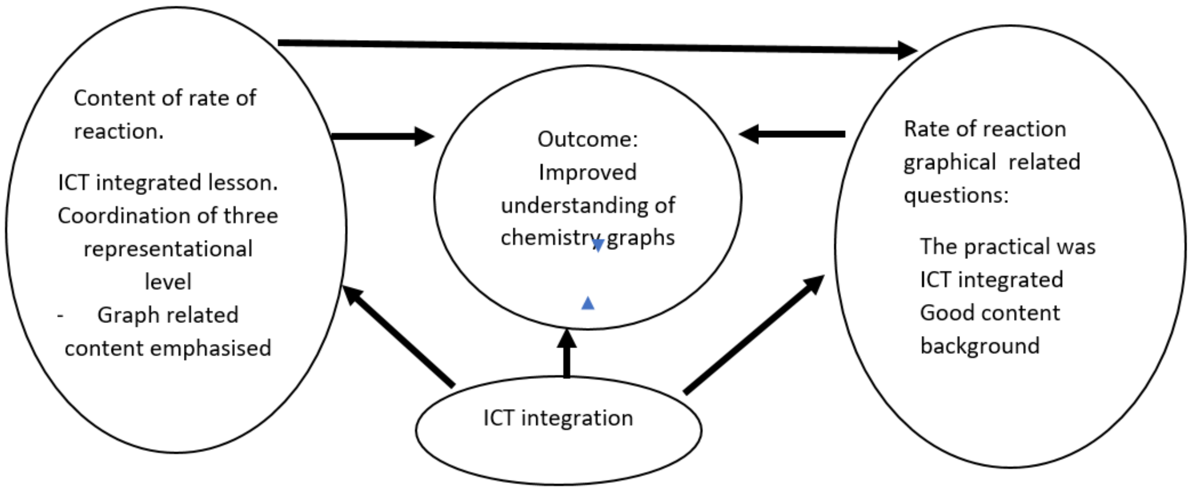


Figure 19*: Rate of reaction summary and outcome*

Chemical equilibrium summary:

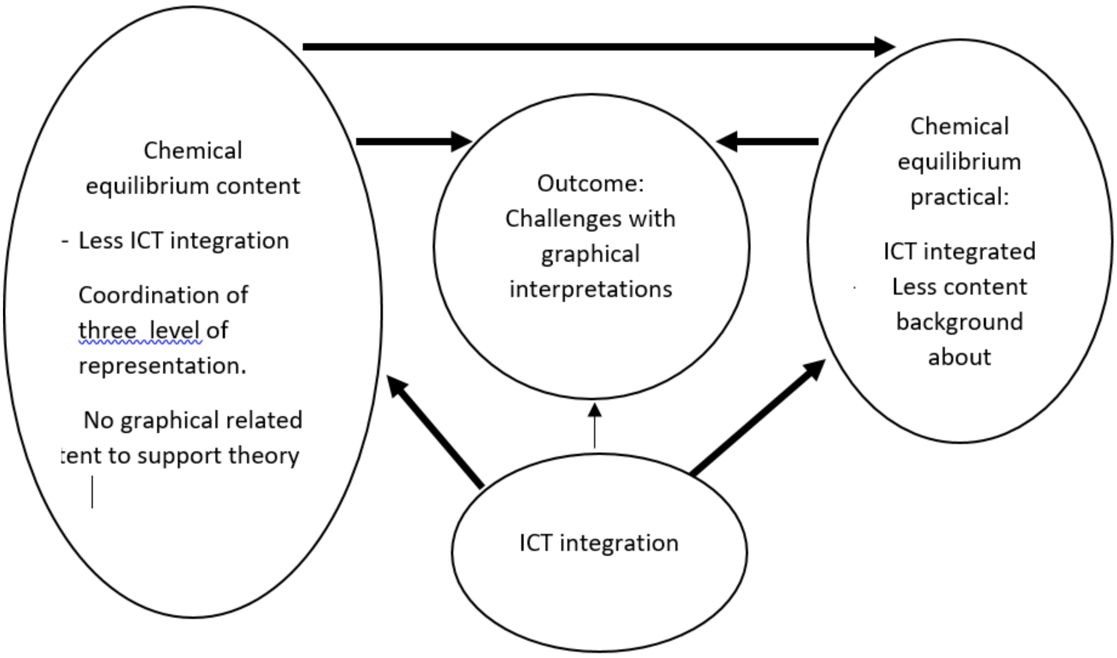


Figure 20: Content taught showing proficient TPACK evidence.

Major findings from data presented:

- The teacher educator shows awareness of complex interplay of technological knowledge, pedagogical knowledge, and content knowledge. This is evident from rate of reaction which due to this awareness a teacher educator transforms subject matter knowledge and make it accessible to students. Accordingly addresses the possible misconceptions.

Rate of reactions misconceptions addressed:

- Rate of reaction increases with decreasing concentration of reactants. The complex interplay of TPACK allowed the teacher educator to show that rate of reaction decreases, as concentration of reactant decreases since reactants are forming products.
- Increasing temperature can reduce forward reaction thus increasing the reverse reaction rate. Evidence of TPACK allowed a teacher to use a simulation to explain how temperature affect a reaction indicating importance of right energy and right orientation for the formation of products. This allowed the teacher educator to show the correct conception which is that temperature causes a decrease or increase kinetic energy so that the frequency of collisions between the molecules is greater.

- There is a relationship between rate of reaction and chemical equilibrium as concepts of rate of reaction act as prerequisites for understanding chemical equilibrium. Both lesson topics are abstract in nature, they are represented using visuals such as microscopic images and graphical representations.

- Factors that affect rate of reaction, such as temperature also affects equilibrium position.

- The content knowledge taught links with pedagogy applied (practical work), and both these were empowered by ICT for both lesson topics. Literature indicates the importance of students requiring substantial conceptual knowledge and spatial abilities if they are to make graphical interpretations or manipulate representations. Links between content and practical work ensure learners are at better state to interpret graphical related questions.
- Literature shows that learners have an iconic misconception about graphs, as they view graphs as images and not scientific representation of relationship between variables. The complex interplay of TPACK allowed the teacher educator to strategically use

graphs as concepts were explained, in turn assisting students to understand graphs and how they are interpreted.

- 4th year chemistry students interviewed were aware of the links between content taught and practical work. All interviewees agreed that the links helps them understand relationship between variables/concepts to be explored during the ICT integrated practical.
- The teacher educator empowers the practical with ICT, recording a practical in a laboratory then editing it so experimental data such as readings of variables shows, as the practical proceeds. According to literature this assist students to understand the relationship between variables, noting for example if an increase causes a decrease in another variable or a direct proportionality depending on the data shown.
- Teacher educator provides pedagogical choices for 4th year chemistry students exposing the to graphical representation. The lesson makes use of graphs to explain concepts, further simulation is used to transform subject matter making it accessible to students showing and phenomenon and corresponding change in graphical representation. The practical itself has graphical related questions that links to content taught.
- Students undergo video analysis to complete a practical, however they can only interact with a video but cannot be hands on (doing the practical themselves).
- Students competent in Excel tools, are able to plot graphs well and in turn get full marks. Whereas students that are not competent lose marks due ton accurately representing data on a graph.
- ICT integration such as using simulations and graph representation has positive impacts in 4th year chemistry students' graphical interpretations as they all lean towards maximum marks including lower scorers.
- Absence of ICT simulations and graphical representation during a lesson of chemical equilibrium, possibly lack of prior knowledge of chemical equilibrium graphs had a negative impact in 4th year chemistry students. Lower, middle, and higher scores demonstrated misconceptions in graphical interpretation questions on chemical equilibrium, except for one higher scorer who maintain a correct conception.
- Common misconception among the 4th year chemistry students' participants were that equilibrium is only reached at the end of the plateau. The correct conception is that when the rate of forward reaction and reverse reaction are equal then equilibrium is reached (At the beginning of the plateau).

- A misconception in graphical interpretation for chemical equilibrium, students fail to the change in concentration as CO was added to disturb the equilibrium. The students thought a catalyst was added and as a result it responsible for the change.
- Students demonstrated good understanding of Le Chatelains Principles, as the explain that if equilibrium is disturbed due to CO, "the system will react in such a way to counteract the change". This links back to content taught as this concept was explained by a teacher educator using a visual representation, showing competency in technology as he interacted with slide to explain this principle.
- Students admits to usefulness of ICT as given there is a clear visual with clear readings, it becomes easier to identify independent and dependent variables. However, minority claim conceptual understanding is rather a more crucial point toward understand and identifying variables, claiming that in certain topics it is easy but for others it is not therefore basics are important.

Similarities and differences between rate of reaction lesson and chemical equilibrium

Similarities

Table 6: Illustrating similarities between rate of reaction and chemical equilibrium.

<table>
<tr><td>Rate of Reaction</td><td>Chemical equilibrium</td></tr>
<tr><td colspan="2">1. Both lessons showed evidence of TPACK.
2. Coordination of three level of representation.
3. Adequacy in contextually comprehending concepts.
4. Links were found between content taught and practical work conducted.
5. ICT integration to facilitate content/theory and for conducting practical work.</td></tr>
</table>

Differences

Table 7: Illustrating differences between rate of reaction and chemical equilibrium.

Rate of reaction	Chemical equilibrium
Sophisticated level of TPACK was evident	Proficient level of TPACK was evident
Graphical content was evident and supported using ICT	Graphical content was not evident
ICT integration for visuals such as simulations and PowerPoint visuals	Less visuals and only limited to PowerPoint visual
Prior knowledge about graphs re-visited during the lesson/lecture	Prior knowledge about graphs not revisited during the lesson/lecture
Little or no faulty conceptions about graphical interpretations from students	More faulty conceptions about graphical interpretations from students
Outcome suggests improved graphical interpretations/good graphical comprehension	Outcome suggests limited graphical comprehension

Pros and cons of ICT integration from the findings

Pros:

The pros from the findings were found to be consistent with literature:

1. Students can experience a first-hand experience of a phenomenon in a form a visual making it easier to identify variables.

2. Students have shown to improve analysis, describing, constructing, comparing and interpretations of chemistry graphs.

3. When used correct ICT tools such as excel may generate accurate graphs.

4. ICT can empower both lecture lesson/theory (integrating visuals to familiarise students with graphical related content) and practical work improving learners understanding of chemistry graphs.

- Cons**:**

1. Students confuse the use of colour thus arriving at a faulty conception, below is the example when a student was asked about interpreting a graph for rate of reaction simulation as shown in figure 13.

"*Tshepo: Okay. So, looking at this, obviously at the start is a green dot and blue and a red dot rather without a grey dot. But as the reaction proceeds. Uhm… then there start to be a formation of a grey dot. So now going to the graph, what I conclude or draw from this is that, as the red dot gets consumed, arg more of the grey dot gets formed. And then so, the red line will be an indication of the red dot or the red reactant. And the grey line will be an indication of the formation or the indication of the grey dot. So, the formation of the grey dot equals the reduction or consumption of the red dot. Yah, that's what I'm saying*."

The correct conception is that the red graph line represents all reactants that are being used up not only the red dots. This response was from category 2 student.

2. The integration of ICT alone does not help improve students' graphical interpretations, but students must have good understanding of theory/concepts taught.

3. The ICT integration in chemistry practical work limits learners to feel hands on or manipulating the variables themselves which introduces struggles to some students. An example is shown below:

"Mr M: The struggles I think it's it's it's it could be one thing that you don't get to really have the physical touch of whatever you doing 'cause you're just watching since it's it's online so you just watching"

4. ICT tools such as excel benefits those that can use it but not students that are uncomfortable/unable to use it.

5.7 Conclusion

The teacher educator shows awareness of technological knowledge, pedagogical knowledge, and content knowledge. This was evident from the rate of reaction lesson and the chemical equilibrium. TPACK evidence in these lessons prevent student possible misconceptions as ICT was integrated transforming subject matter knowledge, making it accessible to students. The content knowledge taught links were found with chemistry ICT integrated practical work and this was found to make it easier to understand concepts explored. Teachers' educators' pedagogical choices expose students to graphical content and graphical related questions during the chemistry practical work. Exploration of student's chemistry practical evaluation led to findings that ICT does have a positive impact and its absence has a negative impact. Negative impact may not necessarily be blamed to ICT but the basic and poor conceptual knowledge of graphs for chemical equilibrium may play a role in the difficulties encountered by students. Incompetence's in using excel tool to plot graphs is part of reasons students do not get maximum marks in graphical related questions, as a result they rate ICT integration lowly in describing and constructing graphs.

Chapter 6: Discussion findings and conclusion

How do 4th-year university students interpret experimental data by integrating the use of ICT in Chemistry practical work?

6.1 What pedagogical choices are provided for pre-service teachers to expose them to graph interpretations activities in chemistry online practical work?

Teacher educator provides pedagogical choices for 4th year chemistry students exposing them to graphical representation. The lesson makes use of graphs to explain concepts, further simulation is used to transform subject matter making it accessible to students showing the phenomenon and corresponding change in graphical representation. The practical itself has graphical related questions that links to content taught. Links between content taught and pedagogy applied (practical) and how these are empowered by ICT gives rise to a complex interplay of technological knowledge, pedagogical knowledge, and content knowledge (TPACK). The teacher educator shows awareness of complex interplay of technological knowledge, pedagogical knowledge, and content knowledge (TPACK). This is evident from rate of reaction which due to this awareness a teacher educator transforms subject matter knowledge and make it accessible to students. Accordingly addresses the possible misconceptions. Literature shows that rate of reaction and chemical equilibrium are abstract in natures and in turn misconceptions persists in students. Conceptual understanding is directly linked to students' successful interpretation and understanding of graphs. Findings indicate that evidence of complex interplay of TPACK eliminates possible students' misconceptions. Following misconceptions were addressed:

1) Rate of reaction increases with decreasing concentration of reactants. The complex interplay of TPACK allowed the teacher educator to show that rate of reaction decreases, as concentration of reactant decreases since reactants are forming products.

2) Increasing temperature can reduce forward reaction thus increasing the reverse reaction rate. Evidence of TPACK allowed a teacher to use a simulation to explain how temperature affect a reaction indicating importance of right energy and right orientation for the formation of products. This allowed the teacher educator to show the correct conception which is that temperature causes a decrease or increase kinetic energy so that the frequency of collisions between the molecules is greater.

Teacher educator pedagogical choices ensure continuity and knowledge progression for topics of rate of reaction and chemical equilibrium. Literature indicates students should master prerequisites concepts as this could help students understand new knowledge in chemistry, rate of reaction concepts is considered prerequisites concepts for chemical equilibrium (Jusniar, Effendy, Budiasih, Sutrisno, 2020). This indicates the importance of teacher pedagogical choices to prevent future possible misconceptions, establishing a relationship between rate of reaction and chemical equilibrium. There was a relationship between rate of reaction and chemical equilibrium as concepts of rate of reaction were useful for students to understand chemical equilibrium. This is evident from exploring the two lessons it was found that Factors that affect rate of reaction, such as temperature also affects equilibrium position. Since these topics are abstract, the teacher educator exposed learners to representation such as microscopic images and graphical representations.

Relationship between rate of reaction is not the sole paramount important consideration in teacher educators' pedagogical choices, also there should be links between content taught and practical work. The content knowledge taught (CK) links with pedagogy applied (practical work), and both these were empowered by ICT (TK) for both lesson topics. Literature indicates the importance of students requiring substantial conceptual knowledge and spatial abilities if they are to make graphical interpretations or manipulate representations. Links between content and practical work ensure learners are at better state to interpret graphical related questions. Literature shows that learners have an iconic misconception about graphs, as they view graphs as images and not scientific representation of relationship between variables. The complex interplay of TPACK allowed the teacher educator to strategically use graphs as concepts were explained, in turn assisting students to understand graphs and how they are interpreted during practical work. The ICT integration of chemistry practical work is a pedagogical choice that exposes students to graphical representations and interpretations. It was found that the teacher educator empowers the practical with ICT, recording a practical in a laboratory then editing it so experimental data such as readings of variables shows, as the practical proceeds. According to literature this assists students to understand the relationship between variables, noting for example if an increase causes a decrease in another variable or a direct proportionality depending on the data shown. Variables contribute to students' graphical interpretations difficulties according to literature as students fail to relate variables presented in turn failing to link these variables with graphs (Gultepe, 2016).

Teacher educators' pedagogical choices summary indicates that ICT integration such as using simulations and graph representation has positive impacts in 4th year chemistry students' graphical interpretations as they all lean towards maximum marks including lower scorers. Absence of ICT simulations and graphical representation during a lesson of chemical equilibrium, possibly lack of prior knowledge of chemical equilibrium graphs had a negative impact in 4th year chemistry students. Lower, middle, and higher scores demonstrated misconceptions in graphical interpretation questions on chemical equilibrium, except for one higher scorer who maintain a correct conception. A common misconception experienced by participants of chemical equilibrium related questions:

1) Chemical equilibrium is reached at the end of the plateau as indicated below where t(s) is 20 seconds:

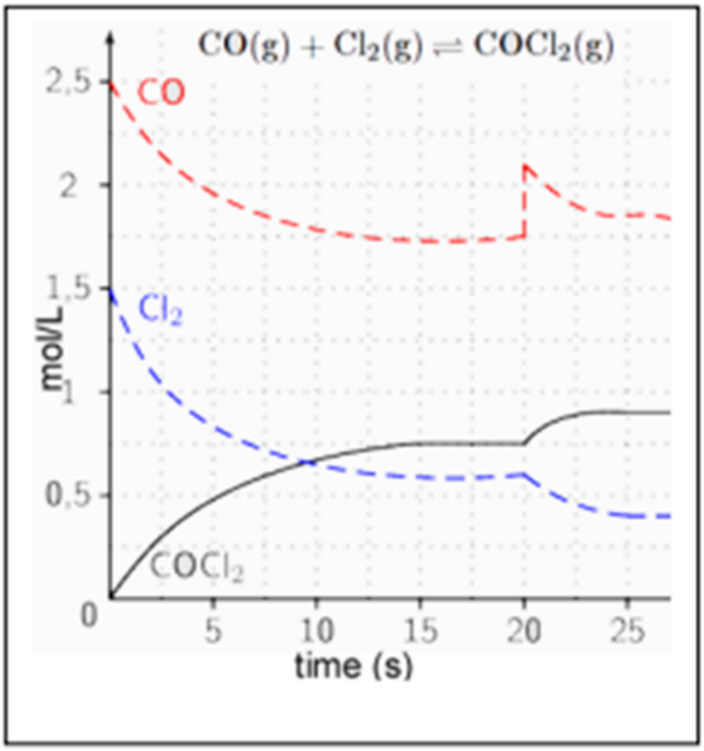


Figure 21: Illustrating the plateau misconception of chemical equilibrium.

- Correct conception is that equilibrium is reached at 15s since at this time rate of forward reaction is equal to rate of reverse reaction.

1. Students fail to explain the CO was added but did acknowledge there is change and guessed it could be a catalyst.

This graphical interpretation question was assessed but in the absence of ICT integration therefore indicated faulty conceptions. This may not be the sole reason as prior knowledge of chemical equilibrium in terms of graphs could be lacking in students. This cannot be linked to teacher educators' pedagogical choices as this is basic knowledge that should have been taught at earlier grades and lower tertiary pre-service teachers programmes years. This signifies the importance of content knowledge (in this case basics) in graphical interpretation, not only ICT may positively affect students' ability to interpret graphs, but also prior knowledge is essential.

6.2 How does the use of video and simulation in chemistry practical work affect 4thyear students' ability to interpret graphs?

The content taught had a simulation used for presenting a phenomenon, and this simulation had graphs. Students were expose to these graphs and accordingly the teacher educator referred to them thus exposing learners to how they can be interpreted. This content taught was linked to the practical work where students were exposed to graphical related questions. The 4th year chemistry students interviewed were aware of the links between content taught and practical work. All interviewees agreed that the links helps them understand relationship between variables/concepts to be explored during the ICT integrated practical. The practical was ICT integrated since it had a video of a practical pre-recorded and had readings on it. Students had to undergo video analysis to complete a practical, however they can only interact with a video but cannot be hands on (doing the practical themselves). ICT affect students' ability to interpret graphs. It was found that statistically the perspective of ICT integrated practical had an impact on their ability to make sense of experimental data graphical. This indicates a statistically significant high number of students in agreement that ICT integrated chemistry practical work has positive effect on interpreting and comparing graphs categories, indicating the impact of ICT integration on chemistry practical work for graphical related questions. This is consistence with literature since according to literature students can experience a first-hand experience of a phenomenon in a form a visual making it easier to identify variables.

However, although all participants acknowledge the impact of ICT in comparing and interpreting graphs, some participants concede that ICT may not have an effect in analysing graphs. Analysing was a concern for students as recorded from interview, students believe that although ICT is useful but basics about graphs is of great importance for students to interpret graphs. Analysing graph was represented by only one participant, whereas the rest of the participants acknowledge that ICT affects their ability to analyse graph, which this is also consistent with literature, students have shown to improve analysis, describing, constructing, comparing and interpretations of chemistry graphs. Graphical construction is also a concern as students who are not competence in ICT tools such as Excel and word to plot graphs struggles and as a result lose marks. One participant claim that ICT makes it difficult to describe graphs, but all other participants believe it makes it easier and as stated above this is consistent with literature. Technological tools require competency, although they offer benefits, but without competency these tools cannot be utilized fully and beneficial. Students competent in Excel tools, are able to plot graphs well and in turn get full marks. Whereas students that are not competent lose marks due to not accurately representing data on a graph. Consistency with literature was observed that when used correctly, ICT tools such as excel may generate accurate graphs. Findings show that ICT tools such as excel benefits those that can use it but not students that are uncomfortable/unable to use it. This concludes that ICT integration in chemistry practical work does allow students to acquire skills of analysis, describing, constructing, comparing and interpretation of graphs.

6.3 Limitations of the study.

The study is based on one chemistry teacher educator thus only the interviewed teacher educator's perspective is considered in this study. Moreover, the study is a small scale as 5 students' participants at 4th year were selected, and they represent the fourth-year chemistry group about challenges in graphical interpretations. A lower number of participants in this study may be a limitation as the findings are only based to 5 student participants. The chemical equilibrium graph had no snippet or simulation as done in the rate of reaction thus students had to rely on their practical work and content taught. This had impact on the outcome of the rate of reaction and chemical equilibrium lessons about ICT integration. ICT integration interviews for students' participants were conducted in different days depending on the student's availability thus this may have affected the results where students share their conceptions/answers about interview questions.

6.4 Conclusions and recommendations.

The study explores the ICT integration in chemistry practical work. The undergraduate students are experiencing difficulties in graph interpretations in science including the topic of chemistry. Poor graph interpretations have been linked to lack of exposure to practical work and practical skills. Practical work offers these skills but considering Covid-19 there is a transition from contact classes to online classes. This means practical work is now online and is ICT-integrated. ICT integrated practical work has proven to offer practical skills and it enhances students graphing skills which are central to graph interpretation. Graph interpretation difficulties makes it impossible for students to exploit the potential offered by graph images. Graphs serve as tools to show relationships between concepts in chemistry and if exploited they contribute to an increased understanding of concepts. This study focused on tertiary level because it has attempted to understand the problem of graph interpretation and how ICT integrated practical work may be useful.

The study explored ICT integrated practical work by answering the main research question, how is video integrated practical work improves 4th years graphing skills in chemistry? This was broken down to understand subjective experiences of teacher educators and 4th year students about ICT integration. The difficulties in graphical interpretations have been indicated to be a result of lack of knowledge about rules and language of graphs, secondly its inadequacy in contextually comprehending concepts, thirdly it is problems related to defining variables presented and linking graphs with these variables, and lastly it is prior knowledge of a graphs content. This study investigated the extent chemistry content taught links with pedagogy applied (practical work) and how these are empowered by ICT (TPCK).

The aspect of chemistry explored are rate of reaction and chemical equilibrium. Rate of reaction and chemical equilibrium were qualitatively analysed in terms of TPACK and activity theory to understand the ICT integration. The outcome was based teachers attempt of linking content knowledge with practical work, accordingly, analysing 4th year students graphical related questions to determine the impact of ICT integration. There was a relationship between rate of reaction and chemical equilibrium because rate of reaction act as prerequisites for students to understand chemical equilibrium. Literature indicates importance of knowledge continuity and progression, as possible misconception in rate of reaction may hinder students' ability to comprehend chemical equilibrium. Rate of reaction lesson examined showed sophisticated level (more advance) of TPACK, more graphical related content was discussed during the lesson. The complex interplay of TPACK allowed the teacher educator to prevent future possible misconceptions. This anticipation comes from a teacher educator showing awareness of TPACK, and in turn transforms subject matter knowledge making it accessible to students, ensuring proper conceptual understanding. Conceptual understanding is directly linked to successful graphical interpretations. The lesson and the practical work of rate of reaction showed links and both were empowered by ICT. The teacher educator pedagogical choices, exposed students on rate of reaction graphical representation, preparing students for graphical interpretation during ICT integrated practical. The outcome indicates improved student understanding of chemistry graphs. This impact was investigated, and participants showed that ICT integration makes analysing, describing, constructing, interpreting and comparing graphs easier.

The chemical equilibrium lesson indicated proficiency level (less advanced) of TPACK, less graphical related content when compare with chemical equilibrium practical work links were found. Practical work and chemical equilibrium were ICT integrated but less compared to rate of reaction. The outcome for chemical equilibrium indicates poor understanding of chemistry graphs. Poor understanding of chemistry graphs affected category 1 (lower scorer), 2 (middle scorer) and 3 (higher scorer). This shows the importance of diagnosing students' conceptions and ensuring their prior knowledge about graphs remains in-check. This may not be linked to teacher educators' pedagogical choices as such knowledge is taught at earlier grades or early years of university study programmes. The teacher educator ensured concepts are taught well and they linked with the practical conducted. Students may have lacked basics from prior years of study programmes, and the practical itself did not include ICT integration in terms of simulations and videos, this may have had an impact in students' ability to make sense of chemical equilibrium graphs. This partly indicates that absence of ICT integration may make it difficult for students to interpret chemistry graphs. Chemistry graph understanding can be improved with ICT integration. ICT integration has shown pros and cons, there is a balance between the two. It is essential to consider the disadvantages of ICT integration to ensure effective use of ICT, accordingly, maximising the advantages offered by ICT integration.

While the search continues for exploring solutions to chemistry graphical challenges experienced by students. The study recommends that future research around this area of research to consider that ICT integration in chemistry practical work alone may not make a notable difference but ensuring the exposure of students to theory and anticipate possible misconceptions before a practical may be useful. The number of participants may be used to understanding a much broader subjective experiences of participants about chemistry graphs and ICT integration. Developing this study, I would investigate how knowledge progression affects students' knowledge/understanding of chemistry graphs over the years of undergraduate level of education. This study has revealed the importance of considering learners prior knowledge before building towards new ideas thus exploring knowledge progression in chemistry content may help chemistry teacher educators determine if students are able to build knowledge or remain with segmented knowledge/pieces of knowledge without links which may prove costly when it comes to graphical interpretation.

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Appendix

Appendix A: Thematic Analysis

Time in minutes	Instruction	Theory/content	TPACK component present	Episode
44:14 – 52:45	Students are instructed to observe and ask questions in relation to concepts discussed.	OK alright so we're now here we are saying when we are starting with the reaction we we start with high concentration of reactants and then with time as these reactants are actually being used they are forming products as you can see here in the concentration of the pro.. of the reactants is decreasing as the time goes on I think maybe it is there's nothing or there's very few (Referring to a visual with a graph). So when you come to this side now here the reaction now is no longer as fast as the beginning because the particles reacting are very very few and now they are far apart and the collisions which should take place are very very minimal so hence now that's why you will find out	CK, TK, TCK, PK, TPK, PCK, TPCK	1

		that the rate of a reaction will always be slowing down if it's not a reversible reaction it goes to completion, if it is a reversable reaction it doesn't go to 0. This is because the particles which we started with the concentration were high that is the number of moles per unit volume were high right but as we go on the number of moles per unit volume is decreasing by second by each second why? is because they're being transformed or the reaction is actually producing reactants so it is now the reactionts which are in higher concentration than the product so you you this is now how you should express your your diagram is the reaction is progressing the rate of reaction decreases and why does it decrease it is because of this issue here. OK that the product the concentration is decreasing per unit time then we have to talk about now the collision right a module called collision theory is used to relate in properties of particles to the rate of a chemical reaction, right with that I would need to demonstrate something here oh God this thing is still loading, what on earth… Oh well there it comes alright so for a reaction to happen there must be a collision right and collision must have the right temperature must have the right orientation the right temperature or the right energy is what you called it activation energy right so I'm gonna start this now so I've given it enough energy in the reaction A is colliding B C and forms a b + C this will happen but now if there is no longer correct orientation you find out that the they can bump into each other but there would be no reaction taking place and now this particular very very few so it will take time for them		

		to collide and it will take time for the reaction to happen now they bound with each other it is not right orientation and there is no reaction taking place so in a reaction for every reaction to take place we need right orientation, right activation energy. Right so to do that now what will happen here I can do now many collisions right uh now I will start up again put it here maybe let me start with 10 and ten of those now there are many right so when we talk of the energy of this we're talking of the average kinetic energy of these 20 molecules alright and they do not have the right energy and you look here an energy profile and we are looking at this activation energy right so the particles which do not have this activation energy this becomes a barrier and then they cannot until we increase the energy of these particles right you can see one is already reacted right that's why we're registering one here and I can put bars so that you can see that something has been found alright but the rate is going very very slow so I will actually maybe the heat it up, look at the temperature it is going up and look at the bar at the average kinetic energy of the particles is going up as well right and there's a lot of collisions but they are not happening at the right orientation with the right activation energy so we still have one uh part of molecules being formed of A, B and C. and but collisions are happening. So when we are talking of collision theory we are saying the particles must have right energy, and the particles must have right orientation so right orientation and corrected activation energy will now give us what you call effective collisions so the rest of the		

		collisions they are not effective because they are not giving us he right orientation together with the right activation energy. OK so, we can actually increase temperature or we can increase the concentration for reactants so if I increase the concentration of the reactants you start to see that the rate of reaction starts to increase right why I am giving in more particles so there are more chances of particles colliding with the right energy with the right orientation so my rate of reaction actually is bound to increase my rate of reaction is bound to increase. it's unfortunate that this one will come back to it when you talk about equilibrium next week, it is a reversible reaction but if it wasn't a reversible reaction what has actually been formed will be actually been isolated from the system and it will not react again but this one is a closed system and it's not an open system. so when you're showing your students you will need to give actually give these disclaimers so that you they really understand that the rate of reaction sometimes the remains still or stationary or constant why because it is an reversible reaction any questions here? OK so when we now just show it like this here it seems it is very very simple uh the right orientation here it's not anywhere else it is here, this is it the right orientation, right orientation and then we form our water molecule if it is hydrogen and oxygen reacting right.		
		OK right so you we've mentioned temperature we we we mentioned the concentration if I have also a demonstrated how concentration and temperature changes the rate of a reaction right and then particle	CK, PK, TPK, PCK, TK	Episode 2

		size this would be concentration in another way right if you bend an match in the atmosphere you will find out that with time it will be dying down and you take this glowing and not glowing but Burning splint which has the little fire now because of oxygen which is little around it and put it in and glass bottle full oxygen you will find out that it rekindles and burns more why? there's more concentrated oxygen here more particles of oxygen than outside now and then that's a that shows you the power of concentration remember concentration is the number of moles per unit volume so if you increase them you increase the rate of a reaction if you increase temperature we are giving the particles energy the same particles with this there having more energy and they are actually maybe surpassing the activated the activated energy the activation energy for them to actually react but with concentration was saying they are having the same particular kinetic energy average kinetic energy and what is happening now is that we are increasing each chances of reaction I mean of collision right so concentration should not be misconstrued with temperature to say it is the same it is not going to be the same so when you're describing where to do the practical of the change in kinetic energy I mean in in heat in the reaction of sodium thiosulphate and acid what are we doing we are adding energy to the particles they are moving fast and as they moving fast they actually increase the chances of having the right orientation and having higher kinetic energy we're raising concentration where increasing the chances of collisions and right orientation without		

		increasing the kinetic energy of the particular reactants.		

Time in minutes	Instruction	Content/theory	TPACK components	Episode
06:31- 09:56	N/A	that only temperature changes the equilibrium constant um partial pressures, concentration and catalyst they do not change the position I mean they the equilibrium constant they only changed the position of equilibrium that is it lies to the left or lies to the right but basically the equilibrium constant does not change only temperature which changes the equilibrium position it's only temperature which changes the equilibrium position the concentration if you look at the if you go back here and uh according to to Le chatelain principle if I add ammonia what will happen this situation is gonna react in such a way as to oppose the addition by favoring the reverse reaction which depletes the amount of ammonia that has been added Student 1: Mr Sipho, sorry uhm are you are you sharing your screen Lecture: Yes, I am I'd asked, and people were saying they are sharing I've started again can you see something now? Student 1: Yes, I can thank you Lecture: OK so I was saying if I add ammonia your reaction is gonna act in such a way as to oppose the addition by favoring the reaction that will deplete the added amount of ammonia so it will favor the reverse reaction and then ammonia is going to decrease and uh the reactants are going to increase the	TCK, PCK, PK, CK	1

		concentration of reactants are going to increase and the concentration of ammonia is going to decrease so the ratio or of actually concentration of equilibrium here is not going to change because here we have actually decreased here we have increased so at the end of the day you will find out that you remain with the same value of your KC unlike in in temperature uh where uh there is a significant change and one side is favoured and as we discussed in last time that the equilibrium if you increase temperature the system will actually favour that which actually absorbed which is the endothermic reaction and if you decrease temperature the system will actually favour that which will release energy which is the exothermic reaction so with the experiment temperature is the only factor that affect the equilibrium constant size or magnitude		
10:42 - 12:44	Calculating the value of constant for the reaction with a lecture.	"and if equilibrium is much less than one much less than one this is partially dissociating it is uh rarely forming products so it would be made, it can be a weak acid weak or base but it partially or a solid it partially dissociates into solution so equilibrium value actually tells us uh the extent to which the reaction will go so when K, uh when equilibrium constant has an intermediate value such as 0, 15 or 50 at the mixture will have significant amounts of both reactant and product It should be 50% right or one generally we say if equilibrium is equal to 1 right it means the concentration of the reactants are equal to the concentration of the product and uh then that's when we find equilibrium constant to be one so we need to really understand and draw information from the equilibrium position constant so it can tell us	PK, CK, TPK, PCK	Episode 2

		about the magnitude of I mean the magnitude of the equilibrium constant can tell us the extent can tell us the magnitude and the amount actually generally of products versus reactants right uh now here we have to calculate a litter of the gas mixture at equilibrium contains these values uh right. Write the expression for the equilibrium constant and calculate the value of the constant for the reaction?”		

Appendix B: Interview session transcription

Mr Sir session about ICT integration in practical work.

Mr Sir interview session.

Researcher: OK welcome Mr Sir how are you

Mr Sir: I'm good I'm good thanks how are you how are you Mr Mzileni.

Researcher: I'm good too no I just I want to ask you a few questions about chemistry practical work and then my questions uh there will be based on the two topics, rate of reaction and chemical equilibrium.

Mr Sir: Oh alright, alright.

Thulebona: Are you OK with that?

Mr Sir: I'm fine, I'm fine

Researcher: OK so I'll just share with you my questions on the screen and then begin is that is is that fine OK

Mr Sir: Its fine with me, fine with me.

Researcher: So before we start I just wanna explain to you and about my study or research

Mr Sir: Okay.

Researcher: Yes so, my research topic is exploring ICT integration in chemistry practical work. So, this is the main question that we are answering but we're gonna answer it using sub questions.

Mr Sir: Oh okay

Researcher: Yes, so that question is how does integration of videos and simulation in chemistry practical work improves 4th years graphing skills?

Mr Sir: Mmmh

Researcher: So, what do I mean by ICT integrated practical work eh this is it's the meaning it means complement complimenting practical work using ICT tools such as computer simulation and modeling tools and video analysis tools and tools for representing and organizing knowledge.

Mr Sir: Mmmh

Researcher: So these tools will be explored to the extent at which they are useful in enhancing students practical and graphing skills and then also it would be examined if OK this part for teacher educators if they actually consider these tools in planning their practical work procedure and questions.

Mr Sir: Okay

Researcher: So, a practical eh it can be like video recorded from a lab which allow learners or students to feel the firsthand experience of the phenomena that is demonstrated in the in that particular video and then if you undergo the video analysis it means you're dealing with ICT integrated practical work and it happens that if you observe like a video practical while recording data this has research shows that this helps students to understand the relationship they working with because they can see from the video and while plotting or drawing that graph it becomes easier to interpret graph in that case or if it's a simulation a simulation it means you're dealing with a different variables and then so a change in one variable it should affect the other variable and in that case also it's a ICT integrated practical work so manipulating those variable also help students to interpret the graph, graphical representation OK so let's move

Researcher: This is our first question but before we answer it, I would like us to see this simulation first so just follow me as I take you through it and then we move

Mr Sir: So, the first topic will be the rate of reaction

Researcher: Yes, yes briefly so, rates of reaction! I just wanna show you this simulation and then I just wanna get from you what do you think is happening here

Mr Sir: Mmmh

Researcher: So, before I start it's a synthetic reaction so a key in understanding this simulation is that there are dots involved it's a synthetic reaction meaning there are two atoms or molecules that are combining to form a what? a product so in this case it's a red dot and green dots which are reactants they're producing a grey dot which is a product

Mr sir: OK

Researcher: OK so here is the actual reaction please observe while you observe the phenomena, please observe what's happening on the graph as well

Mr Sir: Alight, alright

Researcher: and then after I'm gonna ask you to interpret what what the graph means

Mr Sir: Ok

Researcher: starting

Mr Sir: Yeah no I saw I saw

Researcher: Great so looking at this graph like what does it mean maybe I see red a red line and a Grey line what what does it mean what's happening

Mr Sir: So what I think is happening here is that initially initially when before the reaction started there were no products formed and there were only reactants there, then as the time was proceeding here we were able to see some products formed and then after some time where the two lines cross on the graph is where by they they they I can say the reactants were equal to the product and then after some time, more products were formed and then reactants they were decreasing there as the time was proceeding in the reaction

Researcher: Thank you so much Mr Sir yeah come I will just a upload to you a document and then please make ticks and then you you give it back to me

Mr Sir: Alright, alright

Researcher: OK

Mr Sir: So, I'll be able to edit it from right here?

Researcher: You can just download it on your on your PC there and then you make ticks and then you upload it back

Mr Sir: alright alright I will do that just fast fast

Researcher: OK so have, are you accessing it

Mr Sir: yes, I just received it now

Researcher: Thank you

Mr Sir: I am downloading it now.

Researcher: OK so while you busy with that eh let's proceed to the next questions uh how does Uhm links between content knowledge taught and ICT integrated practical work makes it easier for you to understand that relationship explore during online practical work? so this question is asking that before you conduct practical work, they first teach you right?

Mr Sir: yeah

Researcher: Yes, so how does then the links from that content taught if now it links with what you do as part of the practical work does it make it easier for you to understand the relationship you're working with during that practical work?

Mr Sir: when after after the content has been taught

Researcher: Yes, if there are links between what you are taught and what you do is you

Mr Sir: yes it makes it easier for for me to conduct the practical with some concept that I know for example when I'm being taught a certain content I will know what reactants are to be used or let me say what material is to be used to conduct that practical and then what am I expecting to be formed during that practical that means now the product that is to be formed there it gives me a better direction of what needs to be done actually so knowing the content before a practical it makes things easier

Researcher: Thank you and then question number 3, what are your challenges in representing the relationship between concepts investigated during online practical work using graphical representation

Mr Sir: What are the challenges uh can you rephrase the question again?

Researcher: Do you like, do you experience challenges if they maybe they asking you to represent the relationship between concepts using graphs if they say draw a graph representing a particular chemical reaction. Do you experience challenges in there and doing that?

Mr Sir: for me personally no, not at the moment I'm not experiencing any challenges with graphs and the concepts that I will uh I've been taught because having prior knowledge that is prior knowledge of graphs generally speaking it makes things easier to relate it now or connect it with the content being taught in terms of identifying the independent variable dependent variable and then plotting the graph if it is a line graph or bar graph it is a bar graph and all of that so no challenges for me so far

Researcher: Thank you so much Mr Sir and then you mentioned a very important concept eh you mention independent dependent and a control variable so what's what's your understanding on those three concepts

Mr Sir: my understanding is that when we're talking about the dependent variable OK let me start with the independent variable independent variable can be if we are measuring concentration and time for instance Time time is not dependent on concentration during a reaction time is just moving on its own but when it comes to concentration now so we we classify time as the independent variable but when it comes to concentration, concentration is dependent on time for for that specific the time given for it to make a move or to to form a product that is being formed there so the concentration would be the dependent variable meaning it is dependent on time and then we have the controlled variable the control variable there can be the one that we are controlling it can be temperature the the room temperature there it is controlled meaning can remain constant or we are able to adjust it that's what I can see

Researcher: Thank you, Mr. Sir, and then can you easily identify the independent dependent and controlled variable while observing ICT integrated practical work?

Mr Sir: It depends on the information that is given there

Researcher: OK thank you and then how easy is it to use ICT tools such as excel to plot and interpret chemistry graphs?

Mr Sir: it it it is very easy because you just if you have your values, you just go you insert the table there and then you insert the values that you are given there. Eh you identify the independent and the dependent in terms of X & Y axis and then you just put in the values there the graph will be plotted on Excel as compared to doing it manually whereby you have to make equal scales on the graph or busy erasing and jotting down the lines again, so it is very much easier to use the ICT tools there to plot graphs in the chemistry

Researcher: Thank you so much Mr Sir now we move to chemical equilibrium it's a short question, question seven.

Mr Sir: OK I was still filing in this one can you give me a few seconds to fill in this one here? question question one neh. Is it fine if I put an x instead of a tick? Mr Mzileni, Mr Mzileni

Research: Yes, it is fine if you make a tick instead of eh, Its fine if you make an X instead of a tick.

Mr Sir: yeah, is it fine

Researcher: Yes

Mr Sir: oh, OK OK, I think I'm done here so I'm just gonna send it to you now

Researcher: Thank you so much Mr Sir you will let me know if you're ready to proceed

Mr Sir: yeah I'm just gonna upload it here now

Researcher: OK thank you so much

Mr Sir: I am done, it says here I must replace this one, okay let me rename it.

Researcher: OK yes no you can do that

Mr Sir: Done, am done!

Researcher: Thank you so much are you OK to proceed?

Mr Sir: Yes, yes am fine am ready

Researcher: Ok so let's look at this graph here

Mr Sir: yeah

Researcher: can you see it?

Mr Sir: yes, I can see

Researcher: And can you see the time uh the numbers clearly there

Mr Sir: let me make a full screen yeah, I can see that I can see that

Researcher: OK that's good thanks

Mr Sir: Time is in seconds and then mol/L

Researcher: Concentration

Mr Sir: Yes

Researcher: So, looking at this graph how long does this reaction take to reach equilibrium?

Mr Sir: how long does it take to reach equilibrium let me see could you please zoom it in again I can say it takes 15 seconds

Researcher: thank you so much yeah then question number 2 what happened at the 15-minute mark?

Mr Sir: 15 minute you mean seconds neh?

Researcher: Yes, yes

Mr Sir: OK OK the the the, let me say the reaction was in equilibrium

Researcher: Thank you Indicate…

Mr Sir: We see no product being formed there and then it is just a constant reaction

Thank you so much Mr. Sir now the the third question is, indicate how the rates of the forward and backward reaction change at the 15 second mark on the set of axis shown on the right?

Mr Sir: So, I must indicate how the forward and backward change?

Researcher: Yes, what can you say about that?

Mr Sir: Can we come back to the graph please, how the forward and the, yoh this is a difficult one. After 15 seconds How the forward and the backward, yoh ayi this is a tough one!

Researcher: OK we can skip it if you like.

Mr Sir: No no, please let's skip it please

Researcher: Thank you, Mr. Sir, and then was the last one oh, two more, what happened at the 20 second mark?

Mr Sir: Eh can I see the time, what happened at the 20 second mark is that. The reaction became faster and then more, more so CO and then Cl2. The reaction was fast, more, okay at the 20 second mark we can see that the chlorine is decreasing whereas the CO reactant, I can say there was an addition of the CO reactant there in the reaction and then we can see the chlorine reactant becoming less and then the CO becoming more there at that 20 second mark. Then more products were formed also, the concentration was increased there, that’s what I can say, of CO.

Researcher: Thank you so much Mr Sir how does this system respond to the change that occur at the 20 second mark?

Mr Sir: it responds by giving us more more reactant or more concentration of of the of the product I mean not reactant. It responds by giving us more more products or the concentration of the product was increased there. That's how it responded to what happened there at the 20 second mark.

Researcher: Thank you so much Mr Sir and uh it's been a pleasure having you and yes thank you so much that marks the end of our interview session

Mr Sir: yeah, oh alright thank you so did you receive the document there? Can you view it with the ticks?

Researcher: Eh I'm checking OK so….

Mr Sir: Oh, I did not click send I just clicked send now

Researcher: OK great well no it's here!

Mr Sir: Yeah,can you view it with the ticks there or is it still the same?

Researcher: It’s supposed to have changed, yes thank you so much Mr.

Appendix C

Mr M interview session

Researcher: Interviewer: Thank you for doing this so my research topic is this one, sorry about this my research topic is exploring ICT integration in chemistry practical work so the question that I'm gonna be answering is how integration of videos and simulation in chemistry practical work improves for the 4th year graphing skills but then we're gonna answer this question using the sub questions of which are the questions that I'm gonna be asking you

Researcher: So what do I mean by ICT integrated practical work I mean that when we use like ICT tools to complement a practical work such as maybe computer simulations, modeling tools and video analysis tools and tools for representing and organizing knowledge so types of ICT integrated practical work can be a video recorded practical which a video can be taken in a laboratory and then this allows like student to feel the firsthand experience of a demonstrated phenomenon by undergoing video analysis so that's one aspect ICT integrated practical work or it can be a simulation where they showing students simulation of a phenomenon that is being explored and then through that simulation allows student to actually see how one change in in one variable affects the other variable involved in that particular experiment

Researcher: OK so that's just ICT integrated practical work, OK let's move now we're gonna move on to questions before we answer the questions, I want to show you something Mr M and then we we we take it from there is that OK?

Mr M: yes it's right

Researcher: OK so are you still seeing my screen

Mr M: yes I'm still seeing screen there

Researcher: OK good I'm gonna show you a simulation and then I'm gonna ask you to just tell me what you think is happening like the meaning of the graph that you're gonna see OK we here we here here so this is a synthetic reaction

Researcher: Yes so a synthetic reaction means like one one or more atoms or molecules are combining to form a product in this case it's a red dot here combining with the green dots here to form a grey dot so I want you to observe this phenomena inside here and then as you observe the phenomena a graph would be forming and then I want you to tell me what you think or what does the graph means OK

Mr M: OK

Thulebona: OK we are starting (Plays the simulation). Were you able to see that?

Mr M: yes, yes

Researcher: So Mr M what, this graph what does it mean if you were to explain it to someone what does it mean I see there's a red line and there's a grey line, So, what do they mean?

Mr M: So this is the graph of the concentration versus time so it's concentration of reactants and that of of products as time proceeds so it at first we could see that the red graph starts from from the top and in the grey graph starts from the bottom of which means that before anything, before the reaction the products were there hence the red graph is on top maybe we could say maybe the concentration was at 5mol/L, then the concentration of products was at zero because the reaction it was not occurring at that time. And then after when the time now proceeds when the reaction starts to happen, you can see the red graph it goes down then the grey graph it goes up which means that the reactants have been used up to form the product hence they're going down and then the grey graph row it's going up because now products are being formed. There is, the reaction is now happening then they could they continue the graph of the red graph continues to fall up until it stops at a certain time so as the grey graph it continues to rise as it stops at that point there. And then at that point, we could say the reaction has reached an equilibrium so the rates they are equal now. Its still happening but at equal rates

Researcher: Thank you so much Mr M and then we go back to the question before we proceed I want you to, am gonna attached to you a table and then I want you to just fill in that table and then uh it's based on what you were doing on what you were observing on that simulation, is part of that simulation so you just gonna make ticks you're not writing anything just make ticks

Mr M: you will send through an email?

Researcher: Am sending you, you gonna find it in the chats just here on Ms teams

Mr M: Oh, but I wouldn't have to fill it now

Researcher: You you can do it as we proceed to just make ticks and then yeah you send it back here on on either you send it back here in the chats or you send it via email it's fine.

Mr M: yeah, no it seems I will send via mean 'cause I'm using my phone now, this PC is still loading here

Researcher: Alright can we proceed? Are you ready to proceed?

Mr M: it's OK

Researcher: OK thank you this is the table I just sent so….before you you conduct a practical work they need to teach you first right and then so if now the content that you were taught links with what you are doing during the practical work does that make it easier for you to understand the relationship that you're dealing with during that practical work?

Mr M: Can you please repeat the question

Researcher: like if the content taught links with the the the practical work that you are doing does it make it easier for you to understand the relationship between the concept explored during that practical work

Mr M: Oh yes, yes, I think so I think so I think it does

Researcher: Thank you, Mr. M, and then what are your challenges in representing the relationship between concepts investigated during online practical work using graphical representation?

Mr M: The struggles I think it's it's it's it's could be one thing that you don't get to really have the physical touch of whatever you doing 'cause you're just watching since it's it's online so you just watching, your listening to whatever they're saying whoever is manipulating those components and so you can't get the physical feeling that if I increase this thing by 5 whats gonna happen to the independent variable OK let me change it to 2 you know that increasing and decrease feeling that could be a struggle. You only get to understand the concept by hearing them, you just hear them as like you are watching a slide again or the lecture again it doesn't give you the practical feeling.

Researcher :Mmmh thank you Mr M, thank you so much and then what is your understanding of independent dependent and controlled variables

Mr M: OK an independent variable I can say it's a variable that's, maybe say it doesn't depend on anyone it's it's just a variable like time it continues on its own but a dependent variable its now the variable that it depends on what you do on the independent variable, its the dependent variable because it depends on what is being done to independent. Or as the independent increases like you said we had time there, time was the independent variable as time increases what's happening to the concentration at time zero what's happening to the concentration as time increases the concentration decreases. So, a controlled variable its the variable that you can manipulate at any point hence it's a controlled you can increase, decrease it or remove it or add it at any point in time of the practical

Researcher: Thank you so much Mr M and then so can you easily identify the independent dependent controlled variable while observing ICT integrated practical work just just like the one you were dealing with just now can you easily identify these variables

Mr M: I think if if there is a graph or a table you can easily identify like we had a graph there so it was easier to identify the independent and the dependent variable.

Researcher: Thank you so much, and then how easy is it to use ICT tools such as excel to plot and interpret chemistry graphs

Mr M: Uh it's doable it's doable I cannot say it's easy its doable it's not as easy as drawing using your hands, `but you can manage it because there's some there some struggles there that you have there are some things that you have to do there like adjusting your points sometimes the the scale so yeah I can say that's its a bit trickey its not as easy as using hands yeah

Researcher: Thank you so much Mr M and then this is a based on chemical equilibrium now just a short question 7 then we done so if you can look at this graph can you see it is is it visible enough?

Mr M: Can you…Yes yes it

Researcher: It is, okay so looking at this graph and there's a chemical reaction occurring obviously so how long does this reaction take to reach equilibrium?

Mr M: Oh for the reaction to reach, let me see I can say its 20 minutes

Researcher: 20 minutes, thank you Mr and then what happened at the 15 second mark?

Mr M: Oh I can say let's say I'm not sure but I can think that's a transition state that's where now the reactants are forming the products before the equilibrium is being reached

Researcher: Thank you Mr M so in how how is the rate of the forward and backward reaction changed at the 15 second, the rate of the forward and the reverse reaction how did it change from 15 second uh yeah?

Mr M: OK the rate of the forward reaction at 15 second it was decreasing no it was increasing because its forming the product it was increasing. Okay the question says after not at?

Researcher: After like maybe I can give you from 15 to 20

Mr M: Oh 15 to 20

Researcher: Yes

Mr M: No, the rates now there were I can say they were equal because they were reaching equilibrium, so they were equal, flowing at the same rate.

Researcher: Thank you, Mr M, and then come the last question what happened at the 20 second mark

Mr M: Mmh the 20 second mark, I can say that's when they are reaching equilibrium, I guess.

Researcher: Yes, OK thank you thank you and then the last one so how does the system respond to the change that occurred at the 20 second mark?

Mr M: Uhm what I'm seeing there from the graph I can see that the reactants, the concentration of reactants it decreased at a higher rate compared to before because it was decreasing yes but at the 20 second mark it decreased at a higher rate. So I could say the products were being formed now, it was balancing the equation or the reaction so the products can balance with the reactants.

Researcher: No Thank you so much thank you so much for your time so that marks the end of our session and and thank thank thanks Mr M for showing up

Mr M: It's a pleasure

Researcher: Yes, thank you so much man, if you have any questions you can ask but we done we done

Mr M: OK no no no question from my side no questions

Researcher: Thank you so much I'll be expecting the the tick that that uh document

Mr M: Yes, yes no I will send it right now.

Appendix D

Grace interview about ICT integration

Interviewer: So yeah, we gonna be, am gonna start with the questions and then before we start with the question, I want to show you a short simulation and then I'm gonna ask you to interpret uhm a graph there so I'm just gonna show you...

Grace: Sorry I didn't hear you over there!

Interviewer: Yes, I'm saying that before we start answering I am gonna show you a simulation, where you gonna observe a phenomenon and I'm gonna ask you to interpret or to explain what's happening like in the graph

Grace: Oh alright

Interviewer: Uh so I'm just gonna ask you if if you can see clearly everything

Grace: Yes I can!

Interviewer: You can OK so yes this is a synthetic reaction by synthetic reaction it means that it's two or more atoms or molecules combining together to form a product so that's just a basic meaning of synthetic reaction. In this case it's a as you can see it's a red dot combining with the green dots to form a grey dot

Grace: Alright

Interviewer: Yes so, I'm just gonna play this simulation uh a chemical reaction have been taking place and the graph will be forming once it's complete then I will ask you to interpret or to explain what's happening on the graph

Grace: So, I'm expected to explain what is happening on the graph?

Interviewer: Yes so, interpret yeah to interpret like what does it mean like yeah that

Grace: OK

Interviewer: OK yeah am starting (playing the rate of reaction simulation). Okay did you see everything or should I repeat again

Grace: No, I I think I've seen I can try and interpret what is my observation

Interviewer: OK so uhm, please do tell, like let's act as if I don't know anything and then you just explain it to me what's happening here

Grace: Oh alright so from this simulation UM at first we've seen there was OK inside this container there was there were only reactants neh so there was only the concentration of reactants and then the simulation started and then during the chemical reaction um yeah OK on the graph let me just try and interpret the graph during the chemical reaction we've seen that the concentration of reactants were at a peak neh, where they at the highest point and then as time progresses we we are seeing now that we start seeing the concentration of product forming so as the concentration of product increases the concentration of reactants starts decreasing so that is basically what the graph is showing us and then uhm the concentration at uhm at the beginning it is increasing for product and for reactants it is decreasing at a higher rate as compared to uhm as the time progress is now and then yeah with time approaching the end we see that now the concentration of products the rate of concentration of products uhm gets to be equal to the rate of concentration of reactants am i putting it correctly?

Interviewer: Yes, yes, thank you so much thank you so much for that so I'm just gonna quickly send you a table where you need to make ticks based on what you have just observed here and then we're gonna move on to other questions I'm just gonna attach it in the table on the chat

Grace: Sorry?

Interviewer: I'm gonna attach a table under under chats and then you're gonna like, make ticks you not writing you just making ticks on it yes based on what you are observing

Grace: I'm not sure how I'm supposed to do that I'm using my phone

Interviewer: Oh, using it, I can send it it's fine even after this session I will send it via email

Grace: Alright no problem but can I just see it now

Interviewer: Yes, it's just this this table, how does observing ICT practical like went looking crap affect your ability to….

Grace: Oh alright

Interviewer: Yes, then you just make ticks here

Grace: So is it possible or wouldn't it be easier maybe if i give you the answers now and then maybe you will tick

Interviewer: Yes, its fine, its fine even now

Grace: Oh, okay can i just read it one more time, how does observing ICT integrated practical while plotting a graph affect your abilities to analyse a graph (reading a question). Okay can I start answering?

Interviewer: Yes you can answer, am listening.

Grace: So for analysing a graph, how does observing ICT integrated practical while plotting a graph make uhm your ability, affect your abilities to analyse a graph? I think it makes it easier now to analyse a graph.

Interviewer: Mmhhh

Grace: And then describing the graph, it also makes it easier. So this is concerning the simulation we were watching?

Interviewer: Yes, yes, yes

Grace: Okay to construct a graph, it makes it easier also. To compare graphs, it makes it easier. So, can I ask from that other graph that we were observing we had two graphs akere the graph for products and a graph for reactants or was it just one graph?

Interviewer: Yes, it yes two it was two coz like there…

Grace: Oh alright, okay so even the last one interpreting graphs I think it is making it easier, so can you tick making it easier for all of them.

Interviewer: Thank you and then so, okay thank you so much we gonna come back to it. Uhm lets move on to, thank you for that. Let's move back to questions okay (showing questions) sorry, question 2. How does links between content knowledge taught and ICT integrated practical makes it easier for you to understand the relationship explored during online practical work? Now am asking you about practical work remember you did practical on rate of reaction and chemical equilibrium?

Grace: Yes

Interviewer: Yes, so before you do practical work, they need to teach you first, right?

Grace: Mmm

Interviewer: Yes, so if that content uh taught links with uh the practical work does that makes it easier for you to understand the relationship between concepts that you are dealing with during that practical work?

Grace: Yeah, it certainly makes it easier because uhm sometimes uhm you go through their experiment having like uhm the, not necessarily the exact results but knowing exactly like the direction towards uhm, the direction in which you supposed to be going. So, It also helps us to, how can I put this, to to spot even maybe if there are irregularities nyana there they really do help us so I think the pre, pre knowledge does help in these practical's a lot.

Interviewer: Yes, and then uhm what are you challenges in representing, in representing the relationship between concepts investigated during online practical work using graphical representation?

Grace: What are the challenges in representing the relationship between concepts investigated during online practical work using graphical representation.

Interviewer: Yes.

Grace: Yoh its quiet a difficult one, okay.

Interviewer: If you do have any challenges but if you don't have any also its fine.

Grace: Uhm well not that much challenges probably there are challenges but right now I cant really think of any.

Interviewer: Alright that's fine and then question number 4. what is your understanding of independent, dependent, and controlled variables?

Grace: Independent variables are those variables that we are not investigating, uhm how can I put this, okay and then dependent variables neh are the variables that we are investigating. We need to, uhm…can I give an example?

Inteviewer: Yes, you can, I was about to say you can use that graph yeah (Showing concentration-time graph).

Grace: Uhm the graph of concentration vs time, so with concentration vs time uhm the dependent, the independent variable is uhm the time neh, because uhm it is not really depending on anything to change and then the dependent variable is are that which we are investigating so the concentration of reactants and the concentration…like the concentration of reactants and products is the dependent variable because it is depending on time neh. The controlled variables are those variables that needs to be kept constant in order to..to make the investigation more reliable like I can say the the factors such as the temperature it should be maybe constant and if it if it changes uhm maybe it has got maybe the ability to change uhm the results.

Interviewer: Okay

Grace: Yeah

Interviewer: Thank you so much, can you easily identify the independent, dependent, and controlled variables while observing ICT integrated practical work? Like they, for rate of reaction and chemical equilibrium they posted you guys uh videos, in those videos do you think it was easy for you to identify the independent, dependent variables and controlled variables while observing those videos.

Grace: Yeah, I think it's easy to identify independent and dependent variables, with the controlled I I think you need you really need to have you know those basics first before you can say now the controlled are these. Those that you can easily identify are independent and dependent variables only I think it is much more difficult to to identify the controlled.

Interviewer: Great, so uhm how easy is it to use ICT tools such as Excel to plot and interpret chemistry graphs.

Grace: Honestly speaking uhm for me I have not really been using uhm Excel for plotting the graph so…as much as I know how to plot a graph using excel and all those things but I have not been using them and I think even though like I were to be I were to use them it would be, even though in the end I were to come up with a graph and all those things it was not gonna be easy it was gonna take time.

Interviewer: Thank you so we moving to question number 7. Its on chemical equilibrium this one. Uh the first graph that we are analyzed was rate of reaction and now its chemical equilibrium. So, how long…so I am just gonna ask you questions based on this graph and the am just hoping you can see everything clearly. Can you see it? Hello!

Grace: Hello

Interviewer: I am asking if you can see the graph?

Grace: Yes I can see the graph

Interviewer: You can see it, okay that's good so am just gonna ask you questions based on this graph. Uhm so the first question, how long does this reaction take to reach chemical equilibrium?

Grace: How long does this reaction take to reach equilibrium.

Interviewer: Yes

Grace: Mmm okay, I think its 20 minutes.

Interviewer: Okay then what happened at the 15 second mark? Which is this one. What happened at the 15-second mark?

Grace: Mm the rate of reaction…. Okay can I just try and analyse it for a minute. Yeah the concentration of products and reactants uhm stop increasing or decreasing they just remaining constant.

Interviewer: Mm okay so if that's the case what can you say about the rate of the forward reaction and the backwards reaction?

Grace: The rate of a forward reaction and the rate of the….

Interviewer: Of the reverse reaction.

Grace: Sorry can I please see the graph uhm? So uhm on the dependent variable ke, is it concentration?

Interviewer: Yes concentration, uh you looking at 15 to 20 what can you say about the rate of the forward and reverse?

Grace: Mmmh it remains constant.

Interviewer: Okay thank you, the uhm yes what happens at the 20 second mark? What happened at the 20-second mark?

Grace: 20 seocnd mark, uhm yoh there was a drastic change, there was a drastic change for the COCl2 the product. Uhm yoh the rate of reaction increased rapidly, yeah, a rapid increase in the rate of reaction.

Interviewer: Yes, okay thank you so much, thank you so much. And then the last one will be uhm so, how does a system respond to the change that occurred at the 20 second mark? There was a change sso how does the system respond to this change?

Grace: Oh, okay the system react in such a way to counteract the change.

Interviewer: Mmh thank you so much. Uh yes thanks for making time for this, and uhm yes I will send you this table then you can make ticks for me, but we done for now.

Grace: Oh, we done?

Interviewer: Yes we done if you do have any questions you can ask.

Grace: No I have got no questions, I just wanna say I really appreciate to be part of your study

Appendix E

Mr. Chakalaka interview about ICT integration

Researcher: We will be explaining...uh answering the question based on uh the ICT integration and chemistry practical work. So, the main question that we answering is, “how does integration of videos and simulation in practical work at 4th year level chemistry affect students’ ability Interpret graphs?” But then we're gonna answer this question using the sub question that I will be asking you throughout this session and then before we start, I’m just…I will show you a simulation. Uh… A short simulation and then you gonna tell me uh what do you think it's it's happening. So just to confirm with you, can you still see my screen?

Mr Chacalaka: Yes, I can still see your screen

Researcher: OK so Mr chachalaca here uh we have a beaker and then inside this beaker what's gonna be happening is a synthetic reaction. Where a red dot would be combining with the green dot to form a grey dot. So, while this reaction is taking place a graph would be forming here. So, after the reaction is complete, I will ask you to try and interpret eh… what you think this graph means. Okay?

Mr Chacalaka: Okay

Researcher: Cool. So, I will just start with the reaction and then Please observe.

Mr Chacalaka: Ok

Researcher: OK so did you see everything, or should I repeat?

Mr Chacalaka: No, I saw everything.

Researcher: you saw everything?

Mr Chacalaka: Yes.

Researcher: Okay, so I will pretend I don't know anything about chemistry uh can you please try and explain to me like what does this … what's happening in this graph?

Mr Chacalaka: so, in this graph we have concentration versus time number one, and then number two we are experiencing an equilibrium so, as the... before reaction, right?

Researcher: yes

Mr Chacalaka: let's see the red dot is hydrogen and the...is it green? yes, the green dot is oxygen.

Researcher: Yes

Mr Chacalaka: now as the reaction was taking place, the red dot which is hydrogen started with high numbers, I mean high number of reactants, there's a high concentration of hydrogen. And then as you go on with the reaction the concentration decreases until it reaches an equilibrium. Same with um the opposite happens with the green dot, which is oxygen. Now the initial part of the reaction there is no number of um of of oxygen molecules cause as the reaction continues is there is an increase until it reaches an equilibrium. so, uh both reactants reach an equilibrium when a reaction is formed.

Researcher: okay. thank you so much uh... thank you so much Mr Chacalaka. Then I'll post to you this table here so after this but after this session So what do you do in this table you will make ticks so the question is “how does observing an ICT integrated practical work while plotting a graph affect your abilities to...” so you're gonna make a tick uh in this table. Either a tick or a cross.

Mr Chacalaka: alright

Researcher: Alright. OK so let's move to question number two, so question number two, um how does links between content knowledge taught and ICT integrated practical work makes it easier for you to understand the relationship explored during online practical work?

Mr Chacalaka: can you please read the question again?

Researcher: how does links between content knowledge taught and ICT integrated practical work makes it easier for use understand the relationship explored during that online practical work.

Mr Chacalaka: Alright

Researcher: Like what this question is asking is like before you conduct a practical online work they teach you, right?

Mr Chacalaka: Yes, you must content knowledge

Researcher: Yes yes

Mr Chacalaka: Okay

Researcher: so, if that knowledge that you were taught links with their practical work that you that should do, does that make it easier for you to understand the concepts that you dealing with during that practical work?

Mr Chacalaka: so, with content knowledge, right? if you have extensive contact knowledge you know what you are talking about, you know the topics that you are teaching, you have extensive knowledge about what you are teaching. That will help you to be able to come up with a suitable ICT tool to to use for a lesson, for instance, if you are teaching about uh take for instance you are teaching about the reaction we just did. The simulation we just did for instance. Do you know that for you to demonstrate in an equilibrium reaction you will need a graph and you can use a simulation to create the graph? If for instance, you want to explain that the reaction using um life or practical needs you can use a video where are you just... you have two beakers and then you show how the reactions take place of an equilibrium. So, content knowledge helps and prepares you to be able to have… to use the appropriate ICT tool.

Researcher: okay, good. thank you, Um thank you and then Um so what are your challenges maybe in representing the relationship between concepts investigated during online practical work using graphs?

Mr Chacalaka: okay

Researcher: yes

Mr Chacalaka: yah

Researcher: if you didn't get the question, I can rephrase.

Mr Chacalaka: Yah, please rephrase

Researcher: like maybe for for instance they give you uh they say, plot a graph for… for maybe for example for concentration versus time, if they they give you data for concentration and they give you data for time. Uh so do you think you would experience like challenges in representing such using graphs?

Mr Chacalaka: OK so if if the information is extensive and clear, then there will be minimal challenges. However, if the information is not clear for instance when there are different symbols that are used um and there's no consistency. If there's a table between time and concentration and other values are not so clear what the value is or there is no coherence then, from there I think that's when the challenge will come in. however, it's not going to a challenge if if if if the data is present and if the data is clear. I think that that's that's that would be a a shortcoming when comes to graphs however, if the data is clear and well-presented then of course there are no challenges.

Researcher: Argh, Interesting! thank you, so um what is your understanding of independent, dependent and controlled variables?

Mr Chacalaka: OK um so independent variable, um in high school we used to cram this a lot and I think this is what learners also do as well. that independent has to do with whatever you put under independent must be on the X axis and whatever you put under dependent must be on the y axis, right? however just to give it broader context

Researcher: Yes

Mr Chacalaka: Um... independent is a variable that does not necessarily change, usually it has constant values. and it can remain like that. The... the variable can remain like that. it is more needed than the other one. so, what variable depends on the independent. The dependent variable who is usually is the one that either changes or the one that usually relies on the dependent variables for instance, time usually is independent and time always moves forward even in physics. therefore, time is constant or time is just independent, it exists the without the reaction. right?

Researcher: Yes

Mr Chacalaka: and then concentration for instance, concentrations can differ, it can be 10 moles, 5 moles. It can differ and you can control it. you can control it or you can you can manipulate it. Right? Unlike time, time you just set it. then with the constant variable it's a variable that doesn't change, it usually comes… forms a straight line in a graph. Um…Doesn't change, does it does not have a higher or lower value. Just one constant and straightforward value throughout the reaction or the chemical reaction for instance.

Researcher: thank you so much, thank you so much. So, you've been conducting practical like for rates of reaction and chemical equilibrium,

Mr Chacalaka: yes

Researcher: yes, you were using videos there. so, during those practical work can say uh you can easily identify the independent, dependent and controlled variables while observing those practical?

Mr Chacalaka: so, based on the fact that there was a visual representation and the demonstration. It was easy for me to identify the independent and dependent. Unlike when I was given just a table and I was told to plot and and create a graph where I need to show the dependent and the independent. Then that was going to be a challenge because sometimes we mixed things even learners get to mix the two.

Researcher: thank you

Mr Chacalaka: we have you table of concentration and time so you mix it so you don't know which is which. However, through that clear and precise visual representation it was easy for me to identify.

Researcher: Okay, brilliant. uhm so … (coughs) sorry. how easy is it to use ICT tools such as maybe excel to plot and interpret chemistry graphs?

Mr Chacalaka: to be honest, it's quite tricky especially if you don’t have ICT background or you don’t have Microsoft background for ICT. I mean for for excel. it becomes very difficult. so even I personally have a challenge of using excel and understanding how excel works when plotting the graph. usually, I opt for word because it’s easier however it’s not precise or accurate.

Researcher: (Clears his throat) Okay, brilliant. Clears his chest. That was nice. So, we moving moving to the to the last to the last questions. so, it's in now yes, the first graph that we dealt with which was the rate of reaction but now are we focusing mainly on a chemical equilibrium. so here is OK the first one is quite both but now it's precisely equilibrium. so, looking at this graph, I’m gonna zoom it, I’m gonna zoom it so you can see. So, everything that I will ask it’s on this graph.

Mr Chacalaka: it’s based on this graph

Researcher: yes

Mr Chacalaka: Okay

Researcher: can you see it clearly?

Mr Chacalaka: Yes, it’s very clear.

Researcher: So, um how long does it take for this reaction to reach chemical equilibrium?

Mr Chacalaka: um so all of them take about 20 5.5 yeah, I could say 25.5.

Researcher: okay

Mr Chacalaka: wait wait, equilibrium… OK now it gets tricky. cause I'm confused between 20 and that 25. I don't know if this change or its equilibrium. But the maximum time is 25,5.

Researcher: Yes, okay. yes I can… I see what you are talking because there are two equilibriums reached here. So uhm okay, so you you say the first chemical equilibrium raised was in 20 second mark?

Mr Chacalaka: 22 second mark, yes

Researcher: 20 or 15?

Mr Chacalaka: Okay, why 15? I'm trying to ask myself why 15?

Thulebona: no, it's OK

Mr Chacalaka: No, I'm confident with 20

Researcher: Perfect. so, 20 and then the second equilibrium is at 25 comma 5.

Mr Chacalaka: yeah, five yeah.

Researcher: yes, thank you so much. yeah, and then, what happened at 15 mark uh 15 second mark?

Mr Chacalaka: uh OK now it gets tricky but I think that's where equilibrium is initiated

Researcher: okay, brilliant

Mr Chacalaka: yeah

Researcher: Um…So what can you say about the rates of the forward and the reverse reaction between 15 seconds to 20 second mark?

Mr Chacalaka: um so the forward reaction I think is equal to the reverse reaction, hence both reaching equilibrium.

Researcher: thank you so much. okay, so (clears his throat) uh alright. Alright and then what happened at the 20s sorry

Mr Chacalaka: yes

Researcher: yes, well what happened at the 20 second mark?

Mr Chacalaka: There was a change. I'm not sure change in what changing the reaction or change in in equilibrium I'm not sure but there was a change. There was a change maybe a catalyst was added, I don't know. But there was a change

Researcher: OK good. And then so yes, this is the last question this is the last question, so how does the system respond to this change?

Mr Chacalaka: Um … I think the system continues to reach equilibrium furthermore.

Researcher: Okay

Mr Chacalaka: Yah

Researcher: yeah, and I would like to add maybe a question, yeah?

Mr Chacalaka: Ok

Researcher: So, what do you think. Ok let's make it two questions but breaking it down also do you think that a teacher educators slash or lectures are doing uh their best to teach students how to interpret graph or how to plot graphs or they just assume that they know?

Mr Chacalaka: To be honest teachers are going doing a good job but to an extent. Because they just give you necessary information. However, they are not so… they are not explaining to the most clear and detailed manner that even a a first timer chemical uh chemistry student can understand. So, they are making it a bit difficult for them. Like they leave room for them to to struggle a bit.

Researcher: Hm

Mr Chacalaka: So yeah. It's not like learners leave the classroom completely understanding what is required of them when it comes to graph interpretation.

Researcher: So, what do you suggest can be done maybe uh to help students understand graphs better?

Mr Chacalaka: Um I think the most important thing that can assists them is that they need to utilize colors. Utilize colors, utilize a lot of diagrams, utilize um clear and precise pictures eh reduce… reduce notes that are in black and white because learners have different approaches to learning. Some are good in interpreting pictures and some are good in words. Some are good with sound. So, if they can try to utilize sound. I don't know that can stimulate different types of learners into understanding graphs and any other topics that are... they seem complex.

Researcher: Thank you so much. Um that marks the end of our interview session. Thank you so much

Mr Chacalaka: Alright

Researcher: Yes, and then maybe if you go have any questions, you can ask me.

Mr Chacalaka: No, I think I'm very good. Thank you so much for the opportunity.

Researcher: Thank you so much.

Mr Chacalaka: Alright so I should hang up now?

Appendix F

Tshepo interview transcription about ICT integration

Researcher: The question that we are answering is ‘how does the integration of videos and simulation in practical work at 4year level chemistry affect students’ ability to interpret graphs?’. So, we gonna answer this question by looking at sub questions that I am gonna ask you. Before we do that, I would...I would like you to take a look at this. Uhm. Then I’m gonna ask you if you can still see my screen. Can you still see my screen?

Tshepo: I can still see your screen.

Researcher: okay perfect. Just wanna show you something here. And then we will move to questions. We starting with reaction rate.

Tshepo: Okay.

Researcher: Yes. This question is about a reaction rate. So, in this question you will be observing like a simulation. And on the side of that simulation, something will be occurring which is a graph then after that graph has occurred. Or after the reaction is complete, I’m gonna ask you to interpret the graph or to just tell me what does it mean. Is that okay?

Tshepo: yes.

Researcher: uhm yes. So, it’s a synthetic reaction meaning that one or … two or more molecules or atoms are combining together to form a product. In this case, we have a red dot and a green dot. So, they are combining to form a grey dot here. Can you see that?

Tshepo: yah

Researcher: Yes. So, we will be observing this phenomenon in this beaker-like thing and then here it’s a concentration-time graph. It will be…uhm… it will be constructed…uh...over time.

So please observe and then after the reaction is complete, I’m gonna ask you to interpret the graph for me.

Tshepo: Okay

Researcher: Okay. (Clears his throat) So Mr Skhosi I see a red and a grey line on the graph. So, what does this mean. Like would you tell me what does it mean?

Tshepo: Okay. So, looking at this, obviously at the start is a green dot and blue and a red dot rather without a grey dot. But as the reaction proceeds. Uhm… then there start to be a formation of a grey dot. So now going to the graph, what I conclude or draw from this is that, as the red dot gets consumed, arg more of the grey dot gets formed. And then so, the red line will be an indication of the red dot or the red reactant. And the grey line will be an indication of the formation or the indication of the grey dot. So the formation of the grey dot equals the reduction or consumption of the red dot. Yah, that’s what I’m saying.

Researcher: Yes. Thank you so much (clears his throat) Mr Skhosi. And then now we gonna move back to the questions. I’m gonna just send you...arg... a table were you gonna make ticks.

Tshepo: okay.

Researcher: yes. You just gonna make ticks. You not writing anything. Uhm…just ticks. So, I’m gonna upload it here on the chat and then you download it on your side and then you make those ticks. Is that fine?

Tshepo: yes, that’s fine

Researcher: yes. It’s based on what you were experimenting just there. Or observing rather.

Tshepo: okay I’m waiting for it

Researcher: uhm okay. So, I’ve sent it on the chat and then you can send it after... you can send it to me via email after we done. It’s fine.

Tshepo: okay

Researcher: yes, let’s just continue with the questions cause it’s taking so long. Okay. So now we gonna proceed to question number two. So, before you conduct practical work, they… they teach you first, right? They teach you content.

Tshepo: Yes

Researcher: So... so if that content taught links with the practical work, does that…would you say that makes it easier to understand the relationship between concepts that uh you are exploring during that practical work?

Tshepo: okay. Can you recite the question?

Researcher: eh, I’m saying that

Tshepo: so, I’m trying to see if I’m understanding you well. You’re saying that if they are teaching us content and then they relate it or relate it to uhm practical work, does it mean it makes it easy for me to understand the concepts

Researcher: the concepts you are dealing with during that practical work.

Tshepo: oh, that’s the question?

Researcher: yes. Yes.

Tshepo: uh-yes. I believe so, yes because…eh…theory is one thing and I think when I look at it, I think that theory is during that content. During that time when they are teaching us content. So, it’s sort of like theory. But when it comes to practically then turn to use or whatever information that was taught to us uhm and then apply it in practice, during that practical work. So, we get to see it happening or not happening accurately and then whatever the case may be but I think it makes it better to understand during practical, yes.

Researcher: Hmm. Thank you, Mr Skhosi. And then question number three. So, what are your challenges in representation… in representing the relationship between concepts investigated during online practical work using graphical representation?

Tshepo: challenges? Okay. Using graphical… using graphical representations

Researcher: yes

Tshepo: okay. Most common. Okay firstly before I go to that, eh…do you... by graphical representations are you referring to graphs that I then had to go and then construct myself for some.

Researcher: yes

Tshepo: alright. Challenges that I…I…I usually face would come when I have to identify the variable that has to go to the x axis and the variable that has to go to the y axis. And also deciding which one is the independent variable and which one is the depend variable. And in most cases, also which one should be the controlled variable. Although sometimes you can then or I then understand what the meaning of independent variable is and the meaning of the controlled and dependent variables. It still becomes a challenge when it comes to variable, we use during that practical work for me to decide which one. So, with online, the disadvantage of it or the way I see it, I don't think it's… it allows me the chance to learn on my own because I can easily search for it but I think it would have been better to learn how to identify those variables myself. So that's the challenge. Identifying variables.

Researcher: Thank you so much MrSkhosi and then fourth question. So, you mentioned uhm the independent and dependent and controlled variables. So, what is your understanding of these concepts?

Tshepo: okay uh still very minimal. So, what I think the dependent variable is the one that is depends on another variable being changed. Or the change that occurs on another variable. So, the possibility of that variable occurring or that incident happening depends on the change that occurred on another. So, and then the controlled variable I believe it is the one that particular research is being tested on, or a particular hypothesis is tested on. I think that's the controlled variable. And then the independent is the one that… I think it's the one that does not change. It remains constant.

Researcher: okay, thank you Mr Skhosi. And then uhm...the sixth question. Sorry fifth. Yes. So, during online practical work, can you easily identify the independent, dependent and the controlled variables?

Tshepo: uhm, can I easily identify those?

Researcher: yes.

Tshepo: no. Actually no. I can't. I cannot easily identify those.

Researcher: yes.

Tshepo: it usually takes me time and uhm, I need a detailed analysis before I can determine and it doesn't often come easy. It also sometimes depends on what we are working with. So, with other things or with other topics it's not so easy. And with some other topics it is easy to say this is the one that is the dependent and this is the one that is the independent and so forth.

Researcher: Thank you so much Mr Skhosi. And then uh…sixth. Question number six. Ehh... how is easy it to you to use ICT tools such as excel to plot and interpret chemistry graphs?

Tshepo: ai it's not easy. Using excel for example is not is not so easy. So, when it comes to graphs it would then take time for me for example because I'm not so…I'm not or excel is not one of my abilities or yah it's not something that I do well in. Excel for example. So, I'm maybe I could do better using word. I don't even know which commands to punch or which tabs to look for in terms of going to plot a perfect graph on excel. So, it's not always easy.

Researcher: yes. Thank you so much. Uhm so this is question number seven. It's not on chemical equilibrium. It's just four questions. Then we done. So …

Tshepo: okay

Researcher: so please tell me if you can see this graph clearly

Tshepo: yes, I can see it

Researcher: yes, you can see the time? You can see the concentration?

Tshepo: yes, I can see

Researcher: yes. it's a concentration-time graph. And then it's based on the equation which is there on top. So, I'm just gonna ask you questions based on what you see in this graph. So...

Tshepo: hm

Researcher: How long does this reaction take to reach equilibrium?

Tshepo: Okay. Let me see. The time is in seconds.

Researcher: yes.

Tshepo: Uhm, it takes 20seconds.

Researcher: 20seconds. Thank you Mr Skhosi. And then number two. What happened at 15th second mark?

Tshepo: What happened? The reaction was still proceeding. That's what I see.

Researcher: Okay. And then. So, indicate how the rates of the forward and backward reactions changed at the 15seconds mark on sets of axes shown on the right. Maybe you can use 15 to 20 seconds. What can you say about the... the rate of the forward and the reverse reaction in this time interval? 15 to 20.

Tshepo: They are starting to occur at the same rate.

Researcher: Okay thank you Mr. Skhosi. And then question number yes 3. What happens at the 20 seconds mark?

Tshepo: Uhm let me see. Okay firstly, the reverse reaction was occurring at the same rate as the forward reaction. So, the formation of products was equal to the formation of the reactants.

Researcher: Yes. Thank you so much. And then the last one. So how does a system respond to the change that occurs at 20 seconds mark? How does the system respond to a change that occurs at the 20 seconds mark?

Tshepo: Okay. Going back to the graph. Let me see. I see there's increase in the concentration of uhm let me see... if CO. So, when that happens the reaction occurs to consume more of the CO.

Researcher: Hm

Tshepo: As that concentration is consumed. The products COCl2 then is also increased again. So that it will go back to equilibrium.

Researcher: Yes. Thank you so much. Uhm it's been a pleasure having you and that marks the end of our… our meeting. Thank you so much for making time for this. Thanks a lot.

Tshepo: alright, not a problem. Thank you for having me. Apologies about earlier. I had a problem. There was load shedding and I depend on WiFi. So that's why I couldn't join in at that time.

Researcher: Oh, no it's okay, I think uhm I think I wasn't recording. Eish. Thanks. Thanks a lot, man. Thanks.

Tshepo: It shows that you were recording from my side.

Researcher: Oh, yea it does thanks. It's just me. Thanks a lot man. Uhm yea. Uhm. Yah. I'm just gonna leave and then yah. Thanks a lot man.

Tshepo: Uhm so the document that you said you going to send, the table. I still have time on my side so maybe if you can share it via email.

Researcher: Oh yes, it’s based on the simulation. So, I’m just gonna send it via email and you will return it to be as soon as you done with it.

Tshepo: Okay

Researcher: Yes. Thank you so much.

Tshepo: Alright thanks no problem

Researcher: Sure.

Tshepo: Sharp

Appendix G

Lecture transcription for ICT integrated practical work.

Researcher: (clears his throat) uhm okay. Uhm. Okay. So, thank you for coming through. And do the question that we gonna be discussing during this session is ‘what pedagogical choices are provided by the teacher educators to expose students to graph interpretation activities in chemistry during online practical work?’ But we gonna answer this using the sub questions that I will be asking you. So, before we start with the questioning, I would like to explain what do I mean by ICT integrated practical work. So, for ICT integrated practical I… I mean its when you complement the practical work using ICT tools. Tools such as computer simulation. Eh modeling tools...maybe or making use of videos and tools for representing and organizing knowledge. So, I will be exploring if these considered in uh conducting practical work. And accordingly ensuring that students they acquire practical skills and well graphing skills in the process. So (clears his throat) a practical work may be ICT integrated. Meaning that there is a use of ICT tools to construct that particular practical. Such as maybe taking a video and then posting it to students to analyzes and then in doing so the conducting a practical work. And another could be assimilation uh where they showing an experiment and then they students are observing the relationship between the variables maybe how a change in one variable maybe affect the change in other variables. So, a use of simulation as well can be an ICT integrated practical work. So, for now I'll just talk about these two. Uhm because I'm talking about online practical work but there are many. So do you understand uh ICT... what do I mean by ICT integrated practical work or should I add?

Lecture: No, I do understand. I get it very well

Researcher: Thank you so much. Okay. So back to the question. We gonna start. So, if you did not get the question. You have a right to ask them I will repeat the question. If you do not understand the question, you also have a right to ask again. So, I can rephrase the question. Eh so that you can...you can understand it. Are you okay with that?

Lecture: Yes, I'm okay

Researcher: okay thank you. So, question number one. (Clears his throat) So I would like know how do ensure that uh the content knowledge taught links with the ICT integrated practical work for online practical session?

Lecture: The... the first thing which we do is, we cover the content. Uh, I'll give you an example of uh of that we did. Ugh about rates of reaction. We teach the content of rates of reaction and then we do the practical but all this was virtual. Uh for content, I'll prepare slides which I actually presented synchronously with the students. And in an active manner following PowerPoint uh on a synchronized learning. And then after we have a booklet…a practical booklet which we follow which we have converted from face to face to synchronized online learning. and that's what...that's how we ensure that uh uh ICT is integrated in the learning and the practical is also done virtually. Uh and let me end there so that maybe I will not to your further questions.

Researcher: yes, thank you so much and uhm so which ICT tools do you use to conduct online practical work?

Lecture: Uh online practical work, we use uhm prepared experiments which we convert to videos and like the example which I have given you.

Researcher: yes

Lecture: Uh we did rates of reaction where myself and the team went into the lab and we conducted the experiment on the uh precipitation of sulfur, uh where the change or the independent was the temperature. The variable… the independent variable was the temperature. So, we said out water bath from 20 degree. 10 degrees, 20 degrees until 60 degrees in a water bath and we were taking videos. And those videos were actually edited to actually show the reading so that it doesn't become long, you know uh uh we did this over three hours to prepare that.

Researcher: yes

Lecture: But that reduced the video …uh…uh to actually less than 15mins. So that it doesn't become boring to students to concentrate. The readings...eh the variables which were there, the measurements which were there which we took and then they will answer the questions and fill the table. And after filling the table they were graphs which they were supposed to write and then they send the answers online after watching those videos. So that's one of the practicals which we did. And we did also another practical on uh electrochemistry. And that one now was uh the other type, the second type we will be talk about. You know let me just talk about the first one. Then we go ahead with your questions and we will come back to this one.

Researcher: Thank you so much. Uhm while you were answering question number two, I think you did touch on question number three, which was asking how do we use these tools to empower practical work providing the student with practical and graphing skills. So, we can.

Lecture: Alright. On one maybe… what I have left is that uhm in virtual uh uh it's not hands on.

Researcher: yes...

Lecture: It is an observation. But what is important is that they are seeing the manipulation of apparatus which is being done in a real life by a real person. So, they are observing everything.

And then the other skill is for recording, which they are doing on their own and then the third skill now it will be graphical. And the fourth skill now it will be analysis. You have to analyze uh uh uh uh by answering questions. Uhm so my believe is that Chinese proverb which says uh "I see and I remember. I do and I understand. I hear and I forget" so we didn't do it in virtual, we didn't do the I do. But we did the other two which is I see and I remember. So, they were seeing the manipulation of apparatus by my assistants who were doing this practical. So, with this when they are not faced uh with real like situation in the classroom. There were fourth years, next year they will be in classrooms teaching they will remember how the apparatus were manipulated. Unlike when we just take and give them. So virtual of course doesn't have hands on but it will actually give them the skill of actually knowing how to use the apparatus because they have seen it being used.

Researcher: Hmm. Interesting. Thank you so much for this. And then Uhm how do you plan to engage learners in graphical analysis during online practical work? Maybe do you…uhm do you ask graphical analysis related questions during your practical work?

Lecture: Yah on that practical, the first thing was for them to be able to draw to graph. Right? and to actually choose right parameters for the graph and after that, we wanted them re...to check if they really know eh whether these variables give directly proportional or inversely proportional and they had given us the right skill especially of extrapolation and the second one was the line of best fit. And because it was an inverse rate versus the uh uh concentration, and it was supposed to be directly proportional when it is one over t. Right, which gives us that. From that their readings they were not giving them a straight line as such do, they were supposed to actually uh interpret from the theory of practical point of view. To say this should give me a direct relationship. Uh direct proportionally so I must get a straight line. And hence they were supposed now to draw a line of best fit.

Researcher: hm

Lecture: From that. that's what we were analy... wanted them to know. On the analysis part of it they will uh uh be asked now when they have drawn now the life of best fit uh, they will actually be asked what would be concentration at a particular uh of the hydrochloride acid at a particular temperature. They were supposed now to use their graph to actually say at this concentration, the temperature is this due to the relationship between rate and temperature. Those were the two skills we were looking at.

Researcher: thank you so much. Uh thank you so much. And then uh so after conduction online practical work, how do you then evaluate students understanding and like their ability to apply scientific knowledge using graphical representations?

Lecture: Right. Uh I will retardate their answers in the post lab. Uh uh uh, right?

Researcher: hm

Lecture: Actually, they were asked to uh write and answer the questions which were directing them to the skills which we were looking for and we would look at the graphs and their answers that would actually give us an idea if theory and practical works has actually been meaningful. And or learned meaningful with these group of learners.

Researcher: thank you so much. So how do you now measure the effectiveness of ICT practical work in achieving objectives attaining practical skills in practical work session?

Lecture: Right. The measurement is actually on...actually on what the students produced. One, uh did they actually give us the correct readings? Did they record the correct readings? And if they are correct, uh did they draw a proper graph? And did they answer the questions? So, if they did it properly according to the theory they have learned synchronously and the results were fruitful, we got a lot of students doing very well. That's actually gave us the idea that if one has a gone through the videos and was able to answer those questions successfully and uh uh meaningfully and engaging very well, giving us a vivid and clear explanations with the rigor of the subject uh matter, then we were satisfied that uh the ICT was effective.

Researcher: hm, thank you so much. Um, interesting. Um so how do you scaffold the students that are struggling in graphical representations?

Lecture: Alright. Um…scalding now it becomes uh... uh…uh... a problem because uh if the students don't come fourth uh to really uh ask uh that I'm struggling through our platforms uh teams' platforms, messaging and also maybe WhatsApp calling. Uh it will be a problem but with this group we had tutorials.

Researcher: yes

Lecture: And in these tutorials, they were doing it uh virtually as well but asynchronously. Sometimes synchronously but not with the video but only WhatsApp. So that was conferred using our tutorial groups with our tutors and students would actually go there in the room… uh in their different groups. They were put in four groups for tutorials with two tutors. Per group and they would give each other time. That this tutorial is from this time to that time. It was maybe for 45 minutes to an hour. That's when students now would be asking questions and uh being helped by the tutor. But then we before the tutors, us as the chemistry team lecturers will sit down with them, explain the memo to them and we we explain what they actually uh explain…teach to the students so that they understand. Right? So, it was three practicals and some tutorials which would be having a bearing to the practical work they were going to do. So that I think helped that's why we have the majority of them doing her well. Uh but the an... the questions on the tutorials were similar but not exact covering the same concepts but in different ways. And students were able to uh answer the questions. So, the application of knowledge was successive.

Researcher: thank you so much. Thank you so much. Uh now we have just last two questions then we will be done. Uh (clears his throat) so uh accessing students' graphical analysis their interpretation of graphs, do you rely on their prior knowledge of graphs for them to actually interpret or plot graphs or you do make time to teach uh them how to interpret chemistry graphs before they conduct practical work?

Lecture: No. No. No. These are fourth years.

Researcher: yes

Lecture: And we believe that now they are grounded in the knowledge chemistry. And in the practicals skills that is associated with chemistry and one of them is in mathematical expressions and manipulation or for mathematical uh uh uh questions.

Thulebona: yes

Lecture: As well as the graphs. So, from their grade twelves they have been subjected to that so here we are not interested in their application. So, we didn’t have a session dealing with the tutors asking them to drill them but we wanted uh people now ready to be deployed into the teaching pr termite. After passing through four years of learning at higher institutions as well as maybe for FET grade 10,11 and 12 where they are taught these graphical skills. If you look at it, the CAPS documents if you are looking at it.

Researcher: yes

Lecture: In each grade at FET phase, it actually emphasizes the graphical uh uh uh analysis and I mean skills learning of the students.

Researcher: yes

Lecture: So, at higher institution, the students should be now knowing and should be applying that. Maybe they would do it in first year just to remind and check if there are no misconceptions which I mean at a school level but at fourth year level in university applications is the utter most importance to us.

Researcher: yes. Thank you so much. Uh thank you so much for this. And then the last question, uh so when the... you asking about graphical related questions, do you make it a requirement for students to use ICT tools such as excel to plot and interpret graphs or you allow students to make their own choices in terms of plotting uh graphs?

Lecture: Uh looking to...in the fact that we started virtual learning due to Covid-19 and it wasn’t planned but sort of a thing that pounds on us unexpectedly. And we are forced to actually venture into this type of learning.

Researcher: yes

Lecture: Uh it wasn’t compulsory for students to to really uh uh uh use excel. But nonetheless the were some students who showed keenness and interest in drawing uh graphs using excel and they came out very very well. Uh it's only that those who do not know how to use excel to to actually draw the best line of fit. So, you will find that they points would be instead that the best of fit they would be connected from one and it would give you a zigzag. But they have attempted. They have used ICT. It's only that they didn't apply uh uh uh the skill of uh what do you call it? Uh best line of fit. But most or the majority of them they did it very well. Uh those who attempted. But I would put it out of seven and I would say 12,5 percent of them, they actually did use excel. The rest they resorted to manual and using their pencil...paper and graph uh uh then scanning it and then sending it to us.

Researcher: yes. Thank you so much for this wonderful session. So, this marks eh the end of our session. And once again I would like to thank you for making time for this.

Lecture: No, you're welcome. Thank you so much for having me. And I wish you well.

Researcher: thank you. Uh, can I stop the recording.

Appendix H

Heat/rate of reaction Lecture

Lecture: We we need to to record okay. So, every reaction has has got some energy changes in it and chemicals every chemical energy stored as chemical potential energy so it is this energy which will be transferred from one substance to the other or from the system to the surroundings or from the surroundings to the system right uh right so, for example that energy which is contained in gasoline and it can be your diesel it can be your petrol it can be a paraffin and as you heat it actually produces heat it is this heat which is harnessed by the people who actually invented cars for the automobile actually to be driven so those energy changes which takes place there are actually the ones which cause the engine to be extremely hot and those who are driving cars you will know that you need to continuously pour your petrol I mean your water and as well as your fan should be always working to cool down the water so that it can take away the heat from the engine and then we need that heat but if it is too much and there is not controlled it becomes a menacing engine so it is because chemical stores up energy so the heat which is actually being transferred from one substance to the other it is because of the difference in temperature so once there is a difference in temperature then the heat will be moving from high concentration of heat to low concentration of heat or so to speak from hot areas to cooler areas, right so that flow of energy is the one which will be actually studied and the flow of energy is in two ways and that ways endothermic reaction and exothermic reaction right and what happens to the energy of the universe during the chemical or physical process so we have this surroundings as the universe and we have this system as where the reaction is taking place alright so the reaction, the system um can give in give out heat to the surroundings that will be your exothermic reaction or the universe can give heat to the surrounding to the system that will be our endothermic reaction right so that transfer of energy is actually governed by the law of conservation of energy which state that in any chemical or physical process energy is neither created nor destroyed but it is transferred from one form to the other but here it's that form it's only heat which you are tracing here of course sometimes can be light if you pass it through the ‘wires right but this particular it is mainly heat but what we need to know basically is that UM the universe remains unchanged during this process because this is a physical change the heat transfers is a physical change which you comes by the chemical processes of reactions. Alright so we need basically to know that let me maybe share white board here right uh stop sharing yeah and … (big pause)

Lecture: OK alright so basically, we have reactants this side and products that side and then this is the reaction progression which we will be having here right and this would be potential energy in kilojoules per mole so this is energy kilo Joules per mole right so it is increasing in that direction now every particle every substance it has got some potential energy. Right and that energy is being come by due to the process of chemical bonding and remember during chemical bonding the reactions uh they actually happened so that they are at a lower potential energy so there is no system which is it is zero potential in which there is no chemical which is at a zero potential energy they start at a certain point so the reactions or reactants they started at certain point and now here this is what you call Bond breaking right this is point breaking and point breaking needs energy for it to happen for you to break the bonds you need energy and then you come to the activated complex which we are going to talk about later on right and that this is a transition system or a transition state and then from there new bonds are the ones which form or which start to form and then when you are forming new bonds we are losing energy so this side it is losing energy right using so when energy is being lost it depends now whether the energy being lost is more than what reactants contained or what Is contained in the reactants if it is like that now we have our heat of reaction. The products are below the reactants and for us to find the heat of reaction in high school will be saying the sum, OK it's heat of reaction which is delta H is equal to the sum of energies uh or product right of products sorry uh minus sum of react… energies of reactants right now once we get this now you will find that the products here are lower than the reactants so the reactants there's got a higher potential energy let's say 10 and then this one's ideal of potential energy it can be five so when we say 5 - 10 we are going we are bound to get a negative number we are bound to get it negative number right then we say the reaction or the system has lost heat to the surroundings. Right, it has transferred heat to the surroundings rather because they are at the higher potential energy initially now, they lower potential energy so overall the system has actually dissipated some of its heat which it had. So now if in other words we have a system which now it's like this right the product are now here, the products are at a higher energy level right the product side to higher energy level now if we say products minus reactants what you're going to get we're going maybe this is 12 right it will be 12 minus 10 and you get a positive answer and that positive answer is… it shows that the reaction was once a reaction I mean the reaction had a lower potential energy at the beginning with the position of the reactants but at the end of the reaction if the products now are at the higher potential energy and where is this excess heat coming from the excess it is coming from the uh OK can you see my screen guys? OK let me stop can you see now?

Student 1: Yes, we can!

Lecture: Okay let us start again right can you see it now? can we see the screen? (a reply in the chat) OK thank you so much for the feedback so this is how the actual system work how we come up with endothermic reactions and how we come up with exothermic reactions so it means that if it is endothermic reaction this system has actually gained energy from the universe right from which we call the surroundings and if it is exothermic reaction it means that it's system now is dissipated its own energy to the universe which is our surrounding any questions so far? OK right we here so these slides are now describing the reading on your own this is what we were actually talking about on that diagram right maybe here we will need to just give an example we have calcium oxide which reacts with water and then we throw when we actually put a plus this side right we get plus this side it means heat is actually given out to the soundings right but when we actually put the heat beside it means it is gaining. Let me do something here so that I'll be able I usually wants to to write on my slides so let me check if I can write OK yes OK so if heat is on this side right heat is added this side which means it is absorbing but if it ended the way it is this side it means it has actually given out heat. So, this reaction now it is telling us that these reactants are now at higher energy level than this, because some of the heat has been lost so when we have the energy on which we call the enthalpy of change which is the heat of the reaction is here and we are losing this energy then calcium hydroxide is at a lower energy level then we are having an exothermic reaction. Right, so a chemical equation which includes the enthalpy change it is called a thermochemical equation the themo it means it is to you actually telling you or giving information about the heat which has been given in or given out. So, what is the rate of a reaction or is it heat of reaction it is an enthalpy change for the chemical equation and its written as delta H. This should happen at standard conditions and standard condition which is one atmospheric pressure one mole of a substance and 298 Kelvin. So we'll be actually whenever we talk about the heat of reaction and people are doing experiments they'll be using these standard conditions. Right so you be talking about one mole of a substance or all the heat of reactions which will be actually looking at, you need to check whether it is one mole or two moles because the factor of a mole is quite important. This thing we have actually shown that in exothermic reaction chemical potential energy of the reactants is higher than the chemical potential energy in the products alright so as teachers we will need to be able to really explain to the students the reason why we are having those different graphs why are we having those two graphs and we should be able to explain in terms of thermochemistry to these students so that we actually do not create misconceptions on how these issues are actually to take place and now same thing happens with our endothermic reaction if sodium bicarbonate which is your renal tablet you put it in water it will produce sodium carbonate which is the best which you want to neutralize acidic I mean the acids in the stomach uh what happens during that reaction is that heat is absorbed and hence we have 85 KJ this side so heat has been absorbed. OK so I was talking about it number of moles right so the decomposition of two moles of sodium bicarbonate requires 85 Kilo joules of heat therefore the decomposition of four moles of the same substance will require twice as that so here it is two but if it is one then it means we'll be having 85/2 as I was saying it is very very important for you to take note of that. And now we need to really actually be very careful on how we do this uh especially when you are working with gases solids and liquids uh the heat of atomization comes into effect here now I have water when we are actually decomposing water and we use this much but when you are decomposing steam we use this much and there's a difference and then this difference, right is a when you are now changing your state of matter from liquid to gaseous state. So you need to be very very careful when you are doing these equations and you you have to write your state of matter eh so that the examiner and whoever it is your students who need to know which one which state and which energies should be used. Then we come now to heat of solution and heat of solution this is where we are dissolving substances in a liquid or in a solution and we actually uh there's exchange of heat which takes place as well. So, calcium chloride eh when dissolved in water or in the solution so here there will be water this is dissociation right, and then the energy which is produced there is the heat of solution it is called molar heat of solution which means now we are actually looking at one mole, we are actually looking at one mole, one mole of your substance right. So that's how actually we come up with heat of solution in substances which we at secondary level well we are actually calling it dissociation if it is Metallic I mean the compounds ionic compounds and if it is a covalent compounds when they do actually dissolve in water we call it ionization because there is a direct reaction between water particles and water molecules and let's say hydrochloric acid that's why we call it ionization but with calcium chloride there is no direct chemical reactions with take place but it is a physical reaction water surrounding the iron and the potassium ions and chlorine ions and so we don't refer to it as ionization but dissociation and then the heat which is produced there is molar heat of solution right. I've got examples there ammonium nitrate when it is actually being rubbed, there is a the heat of solution there is 25.7 kJ this is are the cold packs which you normally use to really, say take away heat from a swollen injury and so forth what you will be doing there you will be actually taking out heat and as that heat is being taken away it causes this solid crystals of ammonium nitrate to really start to to dissolve and that heat is produced on this exchange of heat of 25, 7 joules per mole. So, key concepts here I'll leave you to to actually maybe study further about heat of fusion, heat of solidification, heat of vaporization and heat of condensation and heat of say combustion right but for this purpose I'm going to actually look at each solution and heat of formation and do some calculations for the heat of formation. And we use heat of formation to calculate heat of reaction I have shown you how we calculate heat of reaction using the energy potential diagrams but now this is what you do in grade 10, and then from grade 11 you need to use heat of formation to really calculate your heat of reaction. Can somebody maybe cheap in here and tell me how do you use heat of formation to calculate the heat of reaction anybody with an idea, let me check my chats you can type you can unmute and talk you can raise your hand all it's fine with me. Anybody? You have been to schools maybe now three years in a row, have you not come across this great 11 piece where you are really heat using heat of formation to calculate the heat of reaction where looking at bond breaking and bone formation that is the heat of formation of reactants formation of all products and then you tell the difference. Anyone who need to come in there? or any questions so far I have some questions? Nhlakanipho?

Student2: Oh yeah, I wanted to know what is the relationship between the heat of reaction and enthalpy are they proportional?

Lecture: To those who were here earlier what did we say when we defining the heat of a reaction, there is a slide which we defined heat of a reaction, anybody who remembers? Heat of reaction is a change in enthalpy right. So, one defines the other, heat of reaction is the change in enthalpy, any other question alright you or you can, you can come to shed light more light on the question OK yes Mduduzi.

Student 3: Uh sir I just wanted to confirm what the question was, I don't think I got the question?

Lecture: OK he wants to know the relationship between heat of reaction and enthalpy, relationship between heat of reaction and enthalpy.

Student 3: OK that's the question you had ask sir?

Lecture: Did you, yes go ahead

Student 3: No am asking if that's the question that was asked by you?

Lecture: Yes, yes that was the question alright OK so if there are no questions lets go ahead. If you are, you can stop me anytime if you actually have a question and we we can discuss and in fact that's how it should be but maybe is it for first day people are hesitant to ask but please feel free to ask and let us engage. So, the heat of reaction at standard conditions is actually calculated using the heat of formation which are called standard heat of formation and we've actually spelled out what we mean by standard conditions and it is actually written and you have to be careful how you actually represent. So this is the enthalpy change delta H and this nought here it means a standard condition, right this is for standard condition OK standard conditions and F represents formation so now the standard heat of formation of a compound is the change in enthalpy that accompanies the formation of one more of a compound from its elements with or substances in the standard states ight so we are looking from an element alright and at standard states that is very very important. Right and then look at them now diatomics sorry or diatomics you will find out that there are designated heat of formation of 0 right at standard conditions but all other elements they do not then they don't have it's an absolute 0 number so they are above zero except for diatomic molecules and then this is now the the heat of reactions so their standard states were saying if it's at room temperature if it is a solid we're looking at a solid, if it is a gas or looking at a gas, if it is a liquid we are looking at that liquid.

Right so you will find out that Bromine it's actually, have heat of reaction in gaseous state why because it's a standard state it's a liquid so for it come from a liquid to a gas you have to actually add in heat so if it is coming from a liquid to a solid as well it would be uh actually taking out heat so it will be below 0. OK alright so these are the standard which you need to refer from time again, so we're saying now for the heat of formation of this you need this much kilo joules for nitrogen you need that and you will find out that all diatomics are zeros this is a diatomic, this is a diatomic, diatomic they are all zeros (pointing/refering to a table of standard heat of formations). And you look at the state if it is hydrogen, if it is in gaseous state conditions so it is 0 but if it becomes a solid now it's no longer zero it will be negative so you need to be very very careful there so these are the values when you will be asked to calculate you can check in your books you or we can check on this slide which will be posted later so that you get the values to be but this is not a conclusive chart of values textbook will we will have those conclusive charts I mean values. So at standard conditions we we we need actually to understand that the heat of formation of products is minus the heat of formation of reactants it gives us our heat of reaction that is our our formula and so if we come back to calcium oxide and water right uh we can take uh the heat of formation of calcium heat of formation of water, heat of formation of calcium oxide we add these two together and we subtract them from that using heat of formation we will get these results I'm not sure if I have a calcium oxide is not conclusive this one, I don't have calcium oxide but I have calcium oxide (solid) which is minus 235, I have water liquid which is minus 285, eight so if I had calcium oxide I was going to actually get uh the heat of formation. so I can from here now I can get the heat of formation of calcium oxide by using this formula right uh so if I add the products at the heat of formation is minus 65 right if I add the product I can get the heat of formation of calcium hydroxide so if you come here right so this is minus 6,5 I mean 65, 2 K joules right which is equal to that of calcium oxide and hydrogen and water plus the heat of formation of calcium hydroxide, right we can calculate that. Right so let's go back here let's take our results at this is the 635. 1 lets take note of this number 635.1 and 285.8 so yeah what is it 635.1 this is minus then we add to minus 285 what is the comma there is it 5 uh it's an 8 right that is an 8 then if we add this now and then we see we take it that side we subtract we are going to get the heat of formation of that. Alright OK and then this one is analysis for actually carbon monoxide in oxygen and I have calculated this one the first thing which you need to do is to balance the equation the equation has to balance and remember the mole ratio is quite important so you need to balance the equations and after balancing equations you start now to look at and calculate you here I'm actually cancelling out the units but you can do without units and you say carbon monoxide what is the heat of reaction carbon monoxide it is - 110, 5 Joules. Right so these are the reactants right and for oxygen it is at its natural state which is a gas so it is 0 and how many moles do we have we've got two right, OK we have got two so this times that will give us minus 221, 0 kilo Joules but remember these are reactants and we need to have products, we need to have products products is carbon dioxide and what is the carbon dioxide is 391, 5 minus 393, 5, 393, 5 right so and also it's two so this will be equal to two multiply by minus 393, 5 which will give us what what is the answer here this is a zero here in this seven there and 8 here and six, seven yeah so this is negative 787. OK correct me if you do you have any complain or having a calculator if I get it wrong correct me and then so this is the heat of formation of the products and the heat of formation of the reactants so heat of reaction now is given by heat of formation is given by the sum heat of formation of products which is minus 787 minus the sum of the formation of reactants OK and then we get our heat of reaction what is the answer? what is the answer? OK give me the answer? Hello? OK this is a 6 this is a 6 we we are subtracting here because this is negative negative double negative give me positive right and then this becomes a 5 and this is negative and it is kilo joules per mole. So, that's the heat of reaction so now you can now it's negative which means like it is exothermic reaction so when I start to draw now I have to draw it like that and then this is my heat of reaction here reactants and products and then that is minus 566 right which is exactly which is here (ticking the answer from the calculation he was making). So when you are describing the rate of reaction we need to really understand these definitions so you will find that at the end of this a series of slides I actually added in the glossary terms so that we really understand what we mean by each term. So, what happens now when the reaction is starting we're starting with high concentration of reactants of reactants…..

Student 4: I have a question sorry

Lecture: Yes

Student 4: Can you go back to your to to that question you've just done right now I just I just wanna understand something or maybe or maybe it's because I joined late, so I just to the part where you did those calculations can you go back to I think it's the second slide where you had your CO2. Another one pass again, oh yes here so you, Oh no no go back, oh no you going very fast hey, again last time. OK yeah here it says calculate solve for the unknown right, so whatever you've been given the reaction you have been the reaction is occurring in one state there right it's all in gaseous form so my question is how is, does the rate of formation take account if let's just say maybe uhm the reactants were gases and then maybe the product was gonna be a liquid how is that gonna affect the whole calculation was it gonna be stay the same or what was gonna happen I joined late so maybe that's why I'm kind of like out of the blue?

Lecture: what happens here this is a gas I'll just take it from here this is a gas for it to be a liquid let's say we form a liquid here carbon dioxide liquid what should happen? you remember a gas it is at a higher energy potential right, it is higher potential energy so we have to take away heat right we have to take away heat here so which means we are losing more heat. OK and so when you come to liquid now we have to come back here uhm do I have carbon dioxide liquid I didn't take it up uh but it should be there for example here it is a gas right bromine is a a gas and now this bromine is a liquid so it is it is going to lose this energy for it to be 0 right, it has to lose this energy for it to be 0. OK so at the heat of reaction where the solid is being formed it will be different from how the heat of reaction when a liquid or a gas is formed that's how I can explain it to you if I have understood your question, you can come back again if you, i missed something are you OK with that?

Student 4: Yes, Sir I'm I'm OK it's it's it's OK I I I get it I get it it's just that I thought like maybe you had to uh no it it's OK for now.

Lecture: Alright no don't worry let's discuss it it's not a problem to discuss that's how we understand OK alright so we're now here we are saying we're starting with the reaction we we start with high concentration of reactants and then with time as these reactants are actually being used they are forming products as you can see here in the concentration of the pro.. of the reactants is decreasing as the time goes on I think maybe it is there's nothing or there's very few so when you come to this side now here the reaction now is no longer as fast as the beginning because the particles reacting are very very few and now they are far apart and the collisions which should take place are very very minimal so hence now that's why you will find out that the rate of a reaction will always be slowing down if it's not a reversible reaction it goes to completion, if it is a reversable reaction it doesn't go to 0. This is because the particles which we started with the concentration were high that is the number of moles per unit volume were high right but as we go on the number of moles per unit volume is decreasing by second by each second why? is because they're being transformed or the reaction is actually producing reactants so it is now the reactionts which are in higher concentration than the product so you you this is now how you should express your your diagram is the reaction is progressing the rate of reaction decreases and why does it decrease it is because of this issue here. OK that the product the concentration is decreasing per unit time then we have to talk about now the collision write a module called collision theory is used to relate in properties of particles to the rate of a chemical reaction, right with that I would need to demonstrate something here oh God this thing is still loading, Oh well there it comes alright so for a reaction to happen there must be a collision right and collision must have the right temperature must have the right orientation the right temperature or the right energy is what you called it activation energy right so I'm gonna start this now so I've given it enough energy in the reaction A is colliding B C and forms a b + C this will happen but now if there is no longer correct orientation you find out that the they can bump into each other but there would be no reaction taking place and now this particular very very few so it will take time for them to collide and it will take time for the reaction to happen now they bound with each other it is not right orientation and there is no reaction taking place so in a reaction for every reaction to take place we need right orientation, right activation energy. Right so to do that now what will happen here I can do now many collisions right uh now I will start up again put it here maybe let me start with 10 and ten of those now there are many right so when we talk of the energy of this we're talking of the average kinetic energy of these 20 molecules alright and they do not have the right energy and you look here an energy profile and we are looking at this activation energy right so the particles which do not have this activation energy this becomes a barrier and then they cannot until we increase the energy of these particles right you can see one is already reacted right that's why we're registering one here and I can put bars so that you can see that something has been found alright but the rate is going very very slow so I will actually maybe the heat it up, look at the temperature it is going up and look at the bar at the average kinetic energy of the particles is going up as well right and there's a lot of collisions but they are not happening at the right orientation with the right activation energy so we still have one uh part of molecules being formed of A, B and C. and but collisions are happening so when we are talking of collision theory we are saying the particles must have right energy, and the particles must have right orientation so right orientation and corrected activation energy will now give us what you call effective collisions so the rest of the collisions they are not effective because they are not giving us he right orientation together with the right activation energy. OK so, we can actually increase temperature or we can increase the concentration for reactants so if I increase the concentration of the reactants you start to see that the rate of reaction starts to increase right why I am giving in more particles so there are more chances of particles colliding with the right energy with the right orientation so my rate of reaction actually is bound to increase my rate of reaction is bound to increase. it's unfortunate that this one will come back to it when you talk about equilibrium next week, it is a reversible reaction but if it wasn't a reversible reaction what has actually been formed will be actually been isolated from the system and it will not react again but this one is a closed system and it's not an open system. so when you're showing your students you will need to give actually these disclaimers so that you they really understand that the rate of reaction sometimes the remains still or stationary or constant why because it is an reversible reaction any questions here? OK so when we now just show it like this here it seems it is very very simple uh the right orientation here it's not anywhere else it is here, this is it the right orientation, right orientation and then we form our water molecule if it is hydrogen and oxygen reacting right. Right so we we spoke about the activated complex which is a transition state which is formed for reaction to take place for this to take place now we will need energy and this is a very unstable a substance which can go either way whether to the product or to the reactants right but mostly to the reactants if the the reaction is actually not in the closed system if in a close system it could go either way without much of a problem. So the activated complex forms only if the colliding particles have enough energy and if the atoms are oriented properly right this is the right orientation which we were talking about when the activated complex is sometimes called the transition state and I think I've used that word before, so this is what we we have now right so the reactions take place here and then they need energy so if they gain that energy we are going to form a transition state and then this transition state now it can go this way or that way but when it goes this way now it has to lose energy and that energy lost actually assist us in bond formation right and then we form our products so with collision theory we have seen that some of the reactants or reactions are very very slow because they won't have the right energy and in chemistry now if your reaction is very very slow unless it is meant to be slow and high yield of products at the slow rate otherwise we always need to actually change the rate of reaction so that it is fast it is economic it is very profitable profitable right so this actually leads us to the rates I mean the factors that affect the rate of reaction who can come in here and talk to us about these factors that affect chemical reaction one of them is temperature what are others can we bring them out or maybe pull through the chats or unmuted and talk. Let's have a discussion and Mduduzi you have a question?

Student 3: So I have a question also a quick question in terms of what you just asked now yeah so I'll start with other factors apart from temperature, it would be the concentration and also the state of division or is it usually called the surface area the area of the given products and then we also have pressure as a factor affecting rate of reaction uh yeah so as far those are the others, that I can immediately remember I know they may be others as well but my question is was the relation in relation to to the activated complex and the transition state I've seen that like even when we were teaching some books use these terms interchangeably however some who actually try to differentiate like some other resources who try to differentiate and the activated complex it would be looked at like you had a representation there which you were using those those spheres to represent the the transition state in the previous slide I think and they would usually the one in the middle so the activated complex would be defined in some of those resources as this configuration where at the atoms are just configured in this way at a particular point in time, and then in terms of the transition state now it just, I think they defined it as it's like where we have just one molecular configuration where it's just the whole thing transitioning so I'm a bit do we use them as a interchangeably or just a thing that doesn't really matter in terms of differences if there are any differences.

Lecture: OK yeah yeah thank you for the convictions and they are quite relevant everybody who can come with also come across this and who can maybe help us here the transition state and the activated complex uhm…

Student 3: uhm sir can I just correct myself yeah so the transition state was kind of defined as you see this one particular one this is the state at which this configuration will transition into either back to the going back to the to the products or moving on to becoming the I mean going back to the reactants and moving on to becoming the product at the same time the transition state is just this one but the activated complex is this range all of them when they are in that particular consideration like a range of them that's how they've defined them, for me it was slightly confusing to actually how do I use them interchangeably or do I just use one activated complex?

Lecture: Right, when we're making these representations, I think we also have to stress that this is particular to hydrogen and oxygen and if I come to other elements and reactants, they will not have this configuration and it's not as usual or as always that we get one a molecule is a activated complex it can be two or three molecules which are coming together. Right I'll give you an example if radicals are being formed right so if I got chlorine and methane reacting my transition state would be these chain reactions right these are temporary molecules which will react either this way or that way so it's not always that we have one molecule as an actual activated complex an activated complex actually is describes uh a temporarily state which is at a higher energy level and which is not sustainable it cannot sustain itself because of this high energy right I I give an example of a physical thing that you are climbing up a tree untill you reach to the apex of the tree branches and are no longer holding you because of your weight and your weight remember it is your mass versus your gravity and your gravity is determined by the distance that you have from the center of the earth so the higher you go the higher the acceleration due to gravity will be acting on you so that it would be actually changing so when you are at that state at the apex of the tree and it can no longer hold you that's what you call it activated complex. Activated to mean that it has got high energy which cannot sustain itself to be in that state it has to lose that energy, for it to be stable and remember the particles should be at a minimum level for them to be stable. So, this activated complex it is that high state which is very very unstable because of the energy which it possess in that state and it has to lose the energy for it to be stable so it can go this way or that way. So the transition now it's loosely used word to mean that it is passing through this phase right it is passing through this phase I would agree that we use more scientific terms than to use a diluted terms like transition so that it can actually give us in English a lot of problems but when we talk of activated complex would be really at home and I think that is what I can say and thank you for bringing that uh I never saw it in that way but I see it let it brings confusion because it can be taught taken from the literal meaning of transition which would be really a problem so we have to stick to our scientific Jaggery activated complex into actually serve us our course without any ambiguity. OK right so you we've mentioned temperature we we we mentioned the concentration if I have also a demonstrated how concentration and temperature changes the rate of a reaction right and then particle size this would be concentration in another way right if you bend and match in the atmosphere you will find out that with time it will be dying down and you take this glowing and not glowing but Burning splint which has the little fire now because of oxygen which is little around it and put it in and glass bottle full oxygen you will find out that it rekindles and burns more why? there's more concentrated oxygen here more particles of oxygen than outside now and then that's a that shows you the power of concentration remember concentration is the number of moles per unit volume so if you increase them you increase the rate of a reaction if you increase temperature we are giving the particles energy the same particles with this there having more energy and they are actually maybe surpassing the activated the activated energy the activation energy for them to actually react but with concentration was saying they are having the same particular kinetic energy average kinetic energy and what is happening now is that we are increasing each chances of reaction I mean of collision right so concentration should not be misconstrued with temperature to say it is the same it is not going to be the same so when you're describing where to do the practical of the change in kinetic energy I mean in in heat in the reaction of sodium thiosulphate and acid what are we doing we are adding energy to the particles they are moving fast and as they moving fast they actually increase the chances of having the right orientation and having higher kinetic energy we're raising concentration where increasing the chances of collisions and right orientation without increasing the kinetic energy of the particular reactants. Right then with pressure now it will be different right OK we talked about particular particle size and you were spot on on particle size now what is happening now here is that these particles in the periphery are the ones to reacting with water the ones in the middle here they are not being reached out by the particles of water or for whatever will be there or hydrogen this is hydrogen and magnesium so this is magnesium and then this is an acid which has got hydrogen ions which must attack these magnesium atoms right so this which are inside the lump here in every set of the lump they are not being exposed to hydrogen atoms or the protons but now when we break them down you will find out that this was all these five I are surrounded by hydrogen all these so the reaction actually would react faster because all particles have been exposed to to another reactant that's why you will find out that the lump will have less rate of reaction the granules and the powder will have a rate of reaction which is very very high why because most of the particles are actually being exposed to react with that the other reactant that's why you find out that dust particles of any nature become very very reactive you will find out that in a mill, sugar mill the dust particles of sugar should not be very very concentrated yeah I mean let being concentrated in Miller because any spark would cause a huge huge fire also in mines of coal mines the dust particles of coal of the coal should be very minimum because we have got methane gas gas particles of coal if any fire happens that will be huge huge explosion right so uh we will actually have to know that particle size actually increases the rate of a reaction. How did i leave pressure, okay uhm let's talk about pressure right uh stop sharing here and then sharing the whiteboard. Or else let me go back to this one, these simulations how can I uhm left out pressure uhm let me see if I can quickly get that alright gas properties (Reading about simulations online), let’s check gas Laws here now these simulations. That’s good right uhm right, now uhm when we are actually talking about pressure I can pump here right, now pressure it is about a particles hitting the walls of the container right and it will Register here because it is measuring how many buzz or collisions which are happening between the particles and the walls on the container but let us talk about these particles you will find out that I will increase pressure as i decrease volume because now the area is now small but the particles are still many right. You look at the pressure right so when you reduce pressure you are reducing the distance the particles are moving and it is now shorter, and they are now actually bumping into each other more frequently. So, you're increasing the chances of collisions you're increasing the number of collisions thereby increasing the number of effective collisions and they are effective collisions is the right orientation, right energy. So, if I further decrease this OK right, you look at the pressure it is very very high right and also pressure can be added by increasing the number of particles. if I continue increasing the number of particles right, I am increasing the chances of collisions yeah right so pressure can be increased in two ways reducing the volume or adding the number of particles right. Right but in other words adding the number of particles you are increasing the number of concentrations the concentration also increases and then we had that increase which you want of collisions. So, pressure increases collisions and if I reduce the volume If if I reduce the volume right and increasingly distance between the particles and they are now moving a little bit much more and that takes time, and that time reduces the rate of reaction.

Student 3: Uh sorry may I disturb you for a moment

Lecture: Yes!

Student 3: Am not sure which screen you are sharing coz what we can see on our end is the whiteboard.

Lecture: Thank you thank you thank you. Oh God I forgot to come back here OK can you see this now?

Yes

Lecture: Alright let me start again OK uhm you can see the particles are moving slowly and uh collisions this is our pressure here is 25 atmospheric pressure now if I remove, reduce my volume right, the pressure is now high it is increasing because I have reduced the distance the particles are moving now they're moving a shorter distance and the chances, I mean I've increased the collision frequency of collision has increased by increasing the frequency of we increase the chances of effective collisions and I said this is one way of increasing pressure but we have got the second way of increasing pressure which is addition of more particles right if I add these particles now there are two many in a given space so collisions that still happen right they're still happening and remember temperatures constant so now what will happen if I increase pressure temperature right I'm keeping this part more energy and yeah moving very very fast right and look at the pressure, right pressure increases why the number of particles bumping the walls of the container are very very high per given second the frequencies increase and that increases rate of reaction right any questions yet? OK I must also check my chats here if it is talking to me alright there's nothing on the chat. OK so let's come back here now right so the particle size will increase and have described it and the pressure we have describe it and now we come to the catalyst. A catalyst many people have got a misconception here. OK let me hear from you what does a catalyst do and how does it achieve that what is the purpose of a catalyst and how does it achieve its purpose?

Student 3: uhm from yeah previous engagements Sir the catalyst actually lowers the activation energy of a reaction so it means that we don’t, the barrier is not as high when you use a catalyst than it was when it was just on its own but key thing about the catalysts is that in that particular reaction it will not necessarily take part it just catalyzes the reaction so that’s what it does. It does not change the initial energy of the enthalpy of the reactants, it doesn't change the enthalpy of the products it just makes the journey from point A to point B quicker if I can put it that way, that’s how I understand it.

Lecture: If I hear you correctly you used the word lowering

Student 3: Yes Sir

Lecture: OK like I just wanted to note that anybody else?

Student 3: So, can I maybe add one more, the one that lowers the activation energy that 'cause there's different types of catalysts, usually we think catalysts are just speeding up some can actually make the reaction slower. So I can also say that there are negative and positive ones and the ones that we use the most even I think the ones that we learn at school level it's mostly just positive kinds of levels which are speed up the reaction

Lecture: OK right even books they talk about lowering or the lower activation energy and then look at my phrasing here. The catalyst permit reactions to proceed along a lower energy path right a given example of right, this is a mountain those have been to Limpopo, let’s say they dug a tunnel or to Cape Town and cars are moving through here this is an alternative path instead of cars moving up hill there and going like that now very few cars will be going up there most of them will be coming down right they cannot reach there. So, realizing that they dug a tunnel right and then they let me and maybe doing this with this one and that's right this is a better way of representing so cars now coming through here they no longer go like that they did not lower lowering you saying you removing this and we remain with something like that then you would have lowered but here we did not lower the mountain we had actually given an alternative route with a lower activation energy. right, it is a lower path those energies or those particles which can go over in a chemical reaction they will use this route right, that's why we have a tremendous increase in the rate of a reaction because all these parts are now being used to actually produce products. So, the we have to correct it as teachers, as student teachers and as you go and disseminate this information to our students during the process of teaching and learning we need to stress this we need to correct this misconception to say that a catalyst lowers the rate of a reaction it gives an alternative path with a lower activation energy. So which means also it gives this is, it has got its own activated complex this one has got another catalyzed activated complex the misconception is coming from putting these two together people will see that this one is lower, the activation energy of this is lower than the activation energy of that but it's not about lowering but it's about giving an alternative route with a lower activation energy and meaning that particles are also going through a different activated complex which does not need much energy. right so the barrier which was there has been circumvented by using a pathway with a lower activation energy. I hope I have made myself clear there alright, yes?

Indistinct chatter from students.

Lecture: Come again?

Student 3: Myself I had a glitch in terms of the lowering part so isn't it we said it's lowering the activation energy so were you breaking that down to say we can't say lowering I mean in the sense of because what I had said initially was that the catalyst will lower the activation energy not the rate of reaction. So in terms of lowering are you referring specifically to the rate of the action or to the activation energy because the question is would I be wrong if maybe I'm looking at two reactions like the same one but one is catalyzed one is not is it incorrect for me to come in with the terminology or rather with the description of lowering to say in this reaction the activation energy was as much and in the other one we used the catalyst and hence the activation energy is lowered. Is this……

Lecture: The term lowered it means we have reduced it; it was high we have cut it down we have reduced it. Hence we are saying the catalyst does not do that it does not do that, but it actually gives an alternative route which has nothing to do with the first path right it gives a different path, but that path is the one which has got a lower activation energy. Like for example I take Limpopo we can go through this and through these mountains you will meet this tunnel right, through N1 right but now you can go through R101 you bypass this one this is 101, R101 you have taken an alternative route with base gradient but it didn't you didn't change the existence of N1 right. N1 exists and all those cars which can go through N1 they're going through N1 this is mostly happening with the trucks when their trucks they don't have their power to go up there they take R101 right and these small cars they will not want to waste time going through R101. So here we haven't had removed or lowered this we have taken an alternative path with a less uh gradient, same here this is an alternative path with a lower activation energy with a different activation activated complex which does not need much we haven’t touched this path it is still there those particles with this high energy they can fly over it right, there's no problem but most of those which didn’t have now they have that energy to surpass this lower activation energy right, that's a big misconception which is even in the books you will find that they use the word lowering the activation activated activation energy they don't lower they give an alternative path right. Then we're talking about the inhibitors is a substance that interferes with the action of a catalyst and some inhibitors work by reaction with or poisoning catalyst itself and thus the inhibitor reduces the amount of catalyst available for a reaction. Reaction slow or even stop when catalyst is poisoned right it is the opposite of what you're talking about that the negative catalyst which lowers but the inhibitors they are actually used to reduce the rate or to even stop the rate of a reaction or sometimes it becomes very very difficult to stop when the present in the presence of a catalyst for a reaction to take place, so they use this inhibitors to stop that reaction. Checkpoint which of the following factors could be increased in order to decrease a reaction rate

Student 5: Yeah

Lecture: Which one is it? Which is the correct one here?

Student 6: It should be the particle size Sir

Lecture: Right uh you have to increase the particle size if you use the lab then the reaction rate will decrease that's correct. OK then you come now to rate laws, uh what is the relationship between the value of this specific rate constant and the speed of a chemical reaction right with rate laws we are now looking at why others are very fast and other particles I mean other reactions are just fast.

I didn't know either I'm confused or something can you please go back to the catalyst part I didn't know it's something it's not getting in me OK stop here. So what you said is that a catalyst does not lower the activation energy you said that it provides an alternative path alternative path for the particles to actually flow over OK. so here's the part that I want to understand you see those two care pots so so if if a catalysis present is gonna provide an alternative part part and then the particles are gonna go to that side but then it the same time there other they can be other particles that can go over through that higher one so my question is it feels like there's gonna be two reactions that are occurring at the same time or I don't know maybe I'm lost you're confused because like if the particles can go through the lower one they can also go through the the one on top at the same time simultaneously so it feels like so it's like the two reactions are occurring at the same time it's like the same reaction occurring at the same time I don't know either I'm confused or something.

Right up let me come back here I know how to get you on board, let's check here look at these particle here it's slow and then it becomes fast just look at one particle, are the particles having the same speed

Student 4: No they don't have the same speed

Lecture: and there are some particles which are very fast

Student 4: Yes yes Sir

Now these particles which are very fast have the ability to go over the higher activation energy because they have that energy but that those particles which are moving slow they've got lower activation energy right and they cannot surpass that barrier in if i introduce a catalyst here now those particles moving at an average kinetic energy they now can surpass, so this is how this is how now the rate of reaction, it is the same reaction but they are going into two different paths and producing the same thing and this product is being produced very fast.

OK we can now I get it makes more sense

But if I remove the particles and close again where we can check it now yeah now slow right and it's not all of them so it is dangerous to say to the kids it lowers the activation energy it's because the catalyst does not do that by lowering you are saying it is taking out heat which is that right and making it minimal. it doesn't have that power right it is actually providing different path and remember itself it is recovered in the end it is not used up, that’s another misconception people have by saying it doesn't take part, it does take part in chemical reaction by giving an activated complex with a lower activation energy but at the end of the day we are going to recover it right into the recovery doesn't mean that it was not participating in the reaction it was participant in the reaction. Is that clear now?

Student 4: Yes so that is that is very clear now I get it it makes more more sense now

Lecture: Thank you very much thank you any question?

Student 3: Sorry sorry Sir yeah so there was I think that explanation really clarified everything, but now doesn't this now change everything about because in those books that they used lowering right and similarly also as a variable you see those exothermic, endothermic curves. The variable at the, on the X axis if the case is that the different particles are going through different things at different times why then do they use time as a as a as a as a variable there because usually it's it's extent of reaction, reaction coordinate so now if these things are not experiencing the same thing at the same time why are we using time as a variable for the exothermic-endothermic curves. I I also used a lot of resources during T.E and the variable in some of them was time, is it that is that correct or it's rooted in the fact that the the the I don't know how the particles actually work. I mean the fact that there's two parts in which these particles can react this is new to me so I'm trying to understand also doesn't not affect now that understanding of using time as a variable in those particular graphs.

Lecture: We don't use time in these particular graphs, we use reaction progression, progress of the reaction right because it is coming from products here I mean reactants to products to the end, we there is no time which we are factoring in here right uh because what it is is a potential energy diagram where were saying this one it is a higher potential energy but the reactants which are here to come to the products they need this much energy and we use a catalyst which would give all give us an alternative route which is lower activation energy most of them now who come lose their energy and come these are losing more energy these are losing much less energy by their chemically same product right so it is there's no time which must be used here.

Student 3: Thank you so much sir.

Lecture: OK as we ask more we will really get to understand and we really get to correct it misconceptions which are out there and these misconceptions have been embedded in us for a long time, if in the textbook which we have been using to pass and the teachers using today today you are told it's a wrong thing it needs a person who really view facts and reasons uh to accept that but that's the fact which is that. Right so the change in concentration that's what we say the rate that's when the time comes in now we are looking at the concentration of one product or at the concentration of one reactant as this one is depleting at a given time or as B is being formed at a given time that is our rate that's where now uh time will come in right. So you will find out that the change in concentration of the reactant is directly proportional to its concentration right the change in it depleting of A is directly proportional to its concentration right and then once we remove a proportionality sign we have to protect constant so we say now the rate is equal to K times concentration so to speak were saying OK we are saying the rate is not equal to K which is the rate specific rate constant times the concentration of A so concentration of A is appearing on the right that's what you call the rate law. Right we've seen this diagram at the beginning now we're seeing it again and we're saying we start with the high concentration of A this is where time now comes in right and not in the potential energy diagrams but in the rate diagrams so as time progresses you remember those boxes where the concentration was changing the number of particles per given time were changing right this is the same thing so we've got fewer particles here of A we have very few particles of A here, we have may be zero particles of A here right. So if it is going like this now this is called the first order reaction right A has a bearing on B directly bearing on the formation of B right uh if it is just by 1/2 then the reaction rate is reduced by half if we reduce A by a quarter the reaction rate is reduced by the quarter they are directly proportional right. So we have a first order reaction right, Higher order reaction reactions like the second order third or the 4th order they come when we are actually looking at that A and B they affect the rate of reaction in other cases it can be only A affecting the rate of a reaction and B does not but if it is like this now for A for the reaction of A with B the rate of reaction is dependent on the concentration of both A and B right and the rate now would be A to the power of X why, B to the power of Y and this is not equal to A this one is not equal to A like what we do in chemical equilibrium right. The X and Y they are determined by experiment they're determined by experiment right those exponents uh they are determined by experiment by, but if X is equal to Y and is equal to 1 then I'll be having one here, I will be having one there and now this rate is called 2nd order because I have to add one and one and I get 2 then it becomes second order that's right we are saying now it is the sum of the exponents of the individual reactants, it is the sum of, and this is obtained by experiment and then we we can also do it by calculation but I have decided because of the short term which we have only had this lesson to do the rate of reaction we cannot go that deep it will be really killing but if we had two lessons we would not actually go and really do that but now I will not bore you with the complications of the calculations of the first orders but you should be able to determine the first or the second order while you are given an equation or to really construct from there. There are notes which are actually I've actually put on each of the sites which you would need to go through as well which complements these PowerPoint, I will also post this PowerPoint. To your reaction mechanism, how do most reactions progress from start to finish right uh for us to understand this will need a balance equation and for example plants use of a carbon dioxide and water in the presence of light to produce oxygen and carbohydrates uh but to simply say that it will be not actually doing justice to the complexity of what actually happened right so in reaction will need to look at the step by step this is what is called elemental reaction which is a reaction in which your reactants are calibrated to products in a single step right in a single step the reaction just go. I'll give this example of calcium oxide if I heat it with then If i just give it heat they will just split into calcium and oxygen that’s a single step. So, it has got only one peak of activation energy and one activated complex right uh but the reaction is they don't do it okay for example if we take oxygen and water for them to react right for them to react right and form carbohydrates it won't be this simple right there's a breaking of the bonds of water or of oxygen and between breaking up these bonds there is one which is very very slow one which is very slow to be broken or to have an activated complex that's what you call the rate determining step. Rate determining step the the rate determining step actually tells us the how fast the reaction can go if you want to improve the rate of reaction with that particular reaction we have to play around with the rate determining step because that is the slower one. The rest will be happening rapidly but in each and every particular reaction which has got multiple steps there is uh one which goes slowly. so they that's what we are saying here so the series of elemental reactions or steps that take place during the course of a complex reaction is called reaction mechanism. so when we are now following each and every path being taken like this reaction to come up with the product we call that reaction mechanism or mechanism of the reaction and all the the steps from the beginning to the end all those which are in between they are called independent I mean intermediate steps so an intermediate is a product of one step in a reaction mechanism and the reactant in the next step and it is a more stable structure and longer lifetime than inactivated complex so that intermediate is becomes a rate determining step. Intermediate do not appear in the overall chemical equation because they either cancel out or like infact they usually cancel out so here we've got this peak with with that peak with that peak with with that peak so in this case now this becomes our rate determining step and then this is they are stable this is another intermediate is another intermediate they are stable why they are at lower potential energy, these are unstable right they are at a higher potential energy right. In multiple step chemical reaction steps do not all progress at the same rate, one step would be low slower than the others as low as step would determine or limit the length of an overall reaction this is what I was been alluding to uh so the chemistry now we have to work around to speed up the rate of reaction by looking and making changes on the rate determining step. This consider this decomposition of nitrogen dinitrogen oxide experiments have shown that the mechanism consists of the two steps shown below right. So the breaking of these two so we will form nitrogen and oxygen atoms this is oxygen atom which is a radical right then this radical will react now more with the nitrogen right and then we now form nitrogen and oxygen. So here the rate determining step that might be the formation of the radical this can be our rate determining step to split we need energy to split that right so after that now this they happen spontaneously and you will find out that this cancels with that they are in the opposite side so it is not in the overall because it is cancels out and then we have our reaction now with O2 instead of O right. Uh so you should be able to actually write this and come up with an overall reaction there might be three there might be two steps which will be taking place and you need to work on that. In the first step you nitrous oxide decomposes into nitrogen gas and oxygen, the oxygen atoms are in intermediate so you must also identify an intermediate here so an intermediate which actually can be appearing on the product and on the reactants that's how easy we identify an intermediate. So to increase the rate of overall reaction you will need to increase the rate of the first step like what I said I will get to that and then if the following reaction mechanism which is an intermediate in the following reaction which is an intermediate uh we have to break this into two radicals and then these two radicals are appearing on both sides and this is so 2A here uh A would be our intermediate that would be our answer there right and then it will also cancel out that's another way to actually determine our intermediate there. Right and then these are the key concepts and the questions and if you go through here you will find that I have given you the glossaries or from the terms which you need to master, do I have questions on my way.

Student 4: So, it's not a question of it's just that I just wanted to say can you please provide us with the textbook that you actually want us to use or I don't know or you just gonna give us slides only or at least but a textbooks would have been much more better so that we can actually yeah

Lecture: Well, I think Wits uses a standard what is what do we use? there is a standard which you have given maybe from part one to part 4 it is the same which are used by honours students what is the name of the textbook please help us?

Student 3: Is it the Giancoli one?

Lecture: Correct! The Giancoli is it on physics

Student 3: Yes we did use it there

Lecture: Yes it has physics there's another one which is similar to Giancoli which is a chemistry one.

Student 3: Is it chemistry and chemical reactivity

Lecture: Uh I'm not sure I will ask solomon if you guys were given that book.

Student 4: Uh Sir it was not he didn't he didn't actually provide us with the textbook he just provided us with the the slides only and the material but then the textbook would have been much more better 'cause you said like as Mududuzi is saying uhm the Giancoli one but then on first semester we used the physics one but then yeah maybe there was a….

Lecture: Yeah there's one I will look for it, its there in the library that's why we use that one at least I think previously people would be buying it, I think students they said they don't make money or needing it that's why they are no longer provided because at the beginning of the your your your first year you will be given the textbook and then it will be put into our account so students did one that I remember now 2016 I think that's when it was added but it was it was it used to be very good to you to get your physics book and others will refuse send the third term, in the third year I won't be taking physics because we use it for natural sciences until until honours it is the sample I'll give it to you on the on the references I'll give it to you it's there in the library

Student 4: Thank you very much Sir thank you

Lecture: Welcome, Just send it to me on private chat so that I don't forget because from now on I'm rushing to another lecture as well so it might slip as I will be talking just send me my number on the chats it has been just added today 0832953226, 0832953226 OK um any questions yeah let me check my chat yeah OK OK it's just acknowledgement alright thank you so much guys keep well keep safe until we meet on Friday during the practical. So, most of the things will be headed up today I will edit in the practical to do during the night today I don't want to bore you with a lot of things because you're writing your test and then uh on this, we were going to write a tutorial for marks and multiple choice I will add all after you have done your test. I don't want to push more work when you are writing your test but at the one for rate uh the tutorial not for marks I have put it there if you get your time find your time just go through them in preparation for your tutorial with marks right but the pre questions for your practical I'm gonna send it today or tomorrow morning and then on Thursday soon after you finish your test in the evening I will actually put in the questions for Marks and then they should be due in the morning of the 6th after of the 19th for our hour lecture so that people will not come to the lecture doing that so normally I want you to use your data overnight until 6:00 o'clock it cuts off on 12 midnight it cuts off and then you submit alright I'm trying to lessen the burden with the pressure which we have which are said to meet halfway. have a wonderful day keep well keep safe bye thank you bye.

Appendix I

Chemical equilibrium lesson transcription

Lecture: Right divided by the concentration of its reactants, raised by the power of coefficients. So this is basically our equation uh where the coefficient actually represents the number of moles according to the balanced chemical equation according to the balanced chemical equations and these we we we had actually dealt with in high school with Kc but you will find out that Kc it is the actually pertaining to concentrations here I'm just writing equilibrium because it is general statement we have partial pressures which is called KP we have acid dissociation which is called KA we have an base dissociation which is called Kb we have solubility product which is called KSP so all these their equilibrium constant but in high school you were only dealing with uh equilibrium constant of concentrations and uh II intended to for us to actually do partial pressures but um looking at the time and the congestion this semester has we are going to skip and it will only maybe attend to equilibrium constant of concentrations only so it is just to revise what you did in grade 12 and not sure if all of us we did our grade 12 because I saw people complaining about Kc uh on the tutorials of which you were supposed just to remind yourself from your grade 12 classes I was so surprised one was saying we never did this but remember education is a continuous it's not actually in pocket it's discreet pockets it is a container So what you learned in grade five grade six grade eight grade 12 and first year it is applicable today you will not say I didn't do it because it's not covered it has been covered in your journey of education I was so surprised to that, i didn't reply to that I just confirmed because others they will really take it politically but in education really is a continuous process where you need to actually build your knowledge from concept previously done right so if we are looking at at this equation our equilibrium constant will be C raised with coefficient at d * d raised with coefficient and A over A which are reactants so these are our products and these are our reactants right and they raised to their powers please look here uh this is a multiple sign it's not an additional sign and then when we are actually talking about symbols chemical symbols we put square brackets when we talk about numbers now we put a normal brackets or give an example and of ammonia right ammonia is end to formation of ammonia and a nitrogen which is three moles here it will give us uh 2 ammonia not three, 2 ammonia right so the equilibrium constant for this one would be equal to uh the concentration of ammonia thats square brackets right over the concentration of nitrogen multiplied by the concentration of hydrogen so this is raised to the power of three this is raised to the power of two according to the balanced equation the coefficient of a balanced equation So what is important is to ensure that you have balanced your equation and then if we are putting numbers just a absolute numbers which I'm gonna give here this will change let's say this is two is now the normal brackets right it's no longer the square brackets if this is 3 and it is 4 I I just want you to see the difference on the numbers if it is our equation or or species of a chemical equation they are always put in square brackets and if it is in numbers they are now put in normal brackets that is very very important if especially when you are teaching uh students there they need to know those differences so you you did an experiment on on this nitrogen di tetraoxide and nitrogen dioxide and the equilibrium position shifted due to the change in temperature if you put it in hot water the equilibrium position will be different when you put it in ice so you need to know that only temperature changes the equilibrium constant um partial pressures, concentration and catalyst they do not change the position I mean they the equilibrium constant they only changed the position of equilibrium that is it lies to the left or lies to the right but basically the equilibrium constant does not change only temperature which changes the equilibrium position it's only temperature which changes the equilibrium position the concentration if you look at the if you go back here and uh according to to Le chatelain principle if I add ammonia what will happen this situation is gonna react in such a way as to oppose the addition by favoring the reverse reaction which depletes the amount of ammonia that has been added

Student 1: Mr Mudadigwa, sorry uhm are you are you sharing your screen

Lecture: Yes, I am I'd asked, and people were saying they are sharing I've started again can you see something now?

Student 1: Yes, I can thank you

Lecture: OK so I was saying if I add ammonia your reaction is gonna act in such a way as to oppose the addition by favoring the reaction that will deplete the added amount of ammonia so it will favor the reverse reaction and then ammonia is going to decrease and uh the reactants are going to increase the concentration of reactants are going to increase and the concentration of ammonia is going to decrease so the ratio or of actually concentration of equilibrium here is not going to change because here we have actually decreased here we have increased so at the end of the day you will find out that you remain with the same value of your case unlike in in temperature uh where uh there is a significant change and one side is favored and as we discussed in last time that the equilibrium if you increase temperature the system will actually favor that which actually absorbed which is the endothermic reaction and if you decrease temperature the system will actually favor that which will release energy which is the exothermic reaction so with the experiment temperature is the only factor that affect the equilibrium constant size or magnitude so the size of the equilibrium constant indicates whether reactants or products are more common at equilibrium right so when a equilibrium question is a large value such as this one a reaction mixture at equilibrium will consist mainly of product such as this reaction mixture is going to completion so if my equilibrium constant is match greater than one right we have more products than reactions it is nearly going to completion right and if equilibrium is much less than one much less than one this is partially dessociating it is uh rerely forming products so it would be made, it can be a weak acid weak or base but it partially or a solid it partially dissociates into solution so equilibrium value actually tells us uh the extent to which the reaction will go so when K, uh when equilibrium constant has an intermediate value such as 0, 15 or 50 at the mixture will have significant amounts of both reactant and product It should be 50% right or one generally we say if equilibrium is equal to 1 right it means the concentration of the reactants are equal to the concentration of the product and uh then that's when we find equilibrium constant to be one so we need to really understand and draw information from the equilibrium position constant so it can tell us about the magnitude of I mean the magnitude of the equilibrium constant can tell us the extent can tell us the magnitude and the amount actually generally of products versus reactants right up now here we have to calculate a liter of the gas mixture at equilibrium contains this values uh right write the expression for the equilibrium constant and calculate the value of the constant for the reaction so as I said we have KC, Keq equilibrium here this should be partial pressures because these are gases but as I said I will not bore you with those details of partial pressures because of the time which we have we need to talk up a lot and we need more lessons on that so I will stick to the equilibrium constant of concentrations so this would be our NO2 and those are square brackets raised to the power of 2 over N2O4 concentration of that right now if I'm putting numbers I put normal brackets so this will be 0,03 raised to the power of 2 over 0,0045 right raised you know to the power of 1 and then that value is gonna give us let me use my calculator here is 0, 03 squared divided by 0,0045 it gave us 20 right give us 20 and then in high school we never spoke about units of Kc generally Kc is a ratio of concentrations and if you know ratios they do not have units but in some circumstances we are going to have an encounter units like this one these are concentrations so the unit of this one will be moles per dm cubed squared divide by moles per dm cubed this is squared so the unit of this one now we just cancelled this and that so the unit of this unit will be moles per dm cubed right that would be the unit so sometimes they ask you to find the unit of that you need just to work with the indices or with the coefficient the coefficients are the ones which gives you the, what we, the unit of the equilibrium constant the unit of the equilibriium constant right up modified general expressions for the equilibrium constant we're just checking uh and these are the number of moles which we had in the calculated that we got 20 right this is just step by step when you are on your own you just go through this step by step right and here we cancel this we cancel that this should give us moles per dm cubed this is but usually we do not write this unit here so you'll find out that these cancels this cancels and I get 0, 2 moles per liter, right the units can be ignored write it is unitless as we reported but if we work with the coefficient or the indices which are there who will always get our unit alright well now we will need to actually it is it is not just obvious to say equilibrium constant will be like this, let me give you one other example that is decomposition of copper of calcium oxide right and then we get calcium plus oxygen this is a gas this is a solid right now the Kc for this one as I said that these are already this one its a solid this one is a solid a solid will actually give me another equilibrium constant which is called KSP so when I'm writing the equilibrium which is not a KSP but that of concentration I do not include the solids because solids and liquids they are a constant like you know a liquid if it is water it will have KW and if it is a solid KSP so it is a constant which is already known so we do not include it so for this one equilibrium position I mean expression it will be only oxygen right that will be the the the equilibrium expression because these two are solid can you give another example of calcium plus water and normally we if it it will give us, calcium hydroxide plus hydrogen gas so this one is aqueous this one is gas and this is a solid this is a liquid now this is two then it is balanced okay right it is balanced is calcium and the equilibrium expression for this one will be K uh equilibrium constant because this is a liquid this is a solid it will not be included in the equilibrium expression so we only include products, times H2 that would be the equilibrium expression so you just have to be very careful to actually check the state of matter for each specie which is in a reaction that is very very important any questions so far? OK there's some yeah OK OK I must check here alright it is balanced this is Calcium and equilibrium expression OK this is me talking OK alright any questions guys? no questions OK so let's continue OK this is just checking the results uh here is another question uh one mole of colorless hydrogen gas and one mole of Violet iodine vapor are sealed in one liter flask and allowed to react it 452 degrees Celsius at equilibrium 1, 56 moles of colorless hydrogen iodine is present together with some of the reactant gases calculate the equilibrium constant for this reaction so it's one more one more initial and at equilibrium we are finding 1, 56 hydrogen iodide okay this one and let me I normally use a table to calculate this I think some of you you know it it's called the table of rice, the rice table I'm just opening the whiteboard OK so I will write this is hydrogen plus iodine and it will give us, and they need to give us hydrogen iodide right so that's the right table OK so in this is the ratio it's 1:2 R represents for the ratio this is a stoichiometric ratio as per balanced equation then initial amount is we are given this will give us one, one and this is 0 right and they tell us that at equilibrium they found 1, 56 right remember the volume is equal to 1 as well they say 1 liter so the volume is 1 dm cubed right so now we look at the change what is the change this one will be 2 - 0, 56 that is the change right uh no no the change is 1,56 that's the change this is it's not the initial there was zero here so this is 0 - 1, 56 that's the change so we get 1, 56 plus the change here right and now according to the ratio this is 2 as to 1 so which means for the formation of these two we will have used one of these so we divide this one by two which will give us 0,78 right that is the change and here this one is to one if it is 0, 78 this one also is 0, 78 now the difference here will give us the reaction I mean what is remained or hydrogen which would be 0, 22 and what is remained here is 0, 22 as well so our Kc or the equilibrium constant will be the concentration of the products raise to the coefficient to its coefficient which is two here and then the hydrogen times the iodide the iodine sorry right which will give us 156 squared times 0, 22 squared why squared? because they have got the same number this is 0, 22 0, 22 so that it would be squared and then what does my calculator give me 1, 56 divided by open bracket 0, 22 close bracket squared so 1,56 divided by 0, 22 squared this is equal to 32, 23 and now this one if you look at it now the indices this is to the power 1 to the power of 1 here is to the power of 2 if you add this they'll give you 2 - 2 so it is zero right this is I'm working out the units so this does not have units it does not take units because the units they do cancel out it does not have units so and also the size here is 32 it tells us that the equilibrium position lies to the left to the right sorry, we have more products than reactants we have more products than reactants at these conditions at these conditions OK any questions? OK let's go back to our……. alright so that's the calculation here OK bromine chloride decomposes to form at certain temperature equilibrium constant for the reaction is that a sample of pure BrCl is placed in one liter container and allowed to decompose at equilibrium the reaction mixture contains 4.00 moles of chlorine and the equilibrium concentrations of uh Br2 that is bromine whats happening now, and bromine chloride so we need to calculate this, whats happening my mouse is playing games with me now right a sample of pure bromine chloride is placed in a one liter container allowed to decompose equilibrium reaction mixture contains 4, 0 moles of chlorine right what are the equilibrium concentrations of Br2 and BrCl at equalibrium you are given the constant here right alright so our Kc or equilibrium constant will be given by okay let me try to use my hand Br2 that is the square brackets here times Cl2 all divided by BrCl squared, square brackets right that's the equilibrium position and this is equal to 11,1 this is equal to 11,1 alright now at equilibrium if we go back to our white board uh right it actually changes here we have got BrCl and we have got chlorine and we then have got bromine this is two then it is balanced then our ray rise right so the value of this one they say is 4 OK and so initially this is the coefficients in ratio right now we don't know oh infact this one was 0 and this one was zero and this is X. OK so now four moles of this one were produced and this is 1:1 so 0 minus that it means it is four that is the difference here it also is 4 so what will form here its also 4 okay so now this is 2:1 if we form one here which means we must actually the ratio is 2:1 so it is 8 here right and then at equilibrium we will be having with minus 8, x minus 8 that is what is there and the volume there is one so our concentration will be divided by the volume of the system which is one if it was two we're going to divide it by two but in this case it is one so if you divide any number by one you get one So what will be the equilibrium position now I mean the equalibrium constant it will be equal to the product is concentration of chlorine concentration of bromine divide by concentration of bromine chloride raise to the power of two so the equilibrium will be now 4 ^2 divide by X - 8 and it is also squared because there is two here and this would be equal to 11.1 OK 11.1 right if I don't want to work with the square roots I can take the square roots of these numbers then this one will be 4 which is equal to the square root of 11, 1 times X - 8 right uh and then for my x this will be equal to 4 minus the square root of 11,1 times 8 eh well this is negative when it comes here it becomes positive so this is positive and all divided by the square root of 11, 1 I've just done quick rearrangement there and what would be the answer let me check here removed the brackets this is 11 the square root of 11, 1x square root of 11,1 times 8 uhm which is negative because there it becomes positive so it is adding here and then you divide that is correct right uh so lets calculate that uh square root of 11, 1 times 8 plus 4 divide by the square root of 1, 11.1 the answer it's 5, 20 right 5, 20 again it is unit lets…. because uh at the top we have got 2 to the power of two at the bottom the power of two so they cancel out which is unitless OK uh these are the things which we need to actually do and I want us to discuss one more a little bit difficult one and our first give it to you so that you can do it and then we will discuss how we will have done it OK it's on word, where is it is it now yeah this one. This one should be degrees right and I want you to do this one and let's see how just tell me how you go about it a 0, 924 moles of A(g) is placed in 1 dm cubed container 300 degree Celsius where it is 38% dissociated when equilibrium was established. Calculate the equilibrium constant for the reaction at the same temperature. how are you going to approach this one let me just give you 5 minutes and we receive what you want is the way to calculate it, five minutes (giving students five minutes to do a calculation).

Lecture: Okay how do we do this? Are you still seeing the screen? Hello? Okay how did you go about it, anybody to suggest? Do I still have people here, okay we still here anybody to suggest how to go about that? Ok, alright for this one then it means we gonna finish early because I had a number of questions to do and then I would discuss with you but there is no cooperation from your side to discuss which means am just gonna do this one then we call it a day. I wanted to do a lot of questions where I correct you or where we correct each other. So let us do this one now 0, 928 of A is placed in that so A is decomposing so here we would be having zero and zero OK and then at equilibrium 30% of A has decomposed theright so uh the ratio is 3 this is the initial number of moles OK and 38% so it will be a 3.8/100 times 0, 928 right. So 38% has dissociated So what is remaining uh it would be, what will be remaining here it will be let us check it out 38,8 divided by a 100 times 0, 928 right this will be what has decomposed

Student 1: Sir it is 0,924

Lecture: Oh thank you so my answer is wrong let me start again 3,8 times 0,924 divide by 100. 3,8 times 0,924 divide by 100 I get 3, 585 I'm putting four decimal places so that my answer will be accurate this is what is actually dissociated right So what is left what is left so this is the change right this is the change So what is left now 0.924 minus the change 0, 3585 this is what is remaining at equilibrium this is the change sorry this is at equilibrium 0, 5655 now this is 3:5 right this is 3:5 So what you have if we change is this one what will be the change here so it will be 5 over 3 multiplied by the change 0,3585 for us to get what is formed here and here it will be 2 over 3 multiplied by 0, 35 to find the change there so this one now it's 5 times 0, 3855. 0, 3585 divide by 3 what did i do now, its 0, 3585 times 5 divide by 3 that is 0, 5975 right so that's what we put here uh my boxes so small OK I will know this is my X I would put my X here and then what is my Y I will I will put my Y here right so 2 x 0, 3585 divide by three it should be 0, 239 that is my x and my volume is 1 so I divided by one I will still get the same answer so this will be my X this will be my Y and now my equilibrium constant would be equal to B square brackets to the power of five multiplied by C to the power of 2 over A to the power of 3 its in numbers right this should be 0, 5655 to the power 5 multiply by my X its is 0, 3585 to the power of 2 all divided by 0, 565 to the power of 3 and if you look here 5 x…. 5 + 2 is 7 divided by 3 which is give us I mean if we are dividing the indices with subtract 7 -

3 is equal to 4 so our unit will be moles per dm cubed to the power of 4. if we remove the brackets what number we get here and the unit will be moles to the power 4 dm cubed to the power of minus 12 that would be the unit. So that's one you can calculate um this one is raised to the power of five, raised to the power of two, raised with the power of three if you have a calculator anybody with a calculator there?

Student 2: Uhm 0,02 moles per dm

Lecture: Those are the units if you want to put units you have to work it precisely you use the indices 5 + 2 - 3 which gives you four and then you put four here as an indices then you remove the brackets to the moles to the power 4 uh over dm cubed to the power of 12. Those would be the units but remember the unit are not that important but if they ask you about the unit is on that in high school we don't look at those units but we are working with ratios, ratios they don't have units right any questions? OK let me stop sharing here and let me bring it up at these questions here but here the first one here what is the equilibrium constant for the reaction expression? can you write the equilibrium constant of this reaction and let's find unit alright what is the answer here?

Student 2: Kc

Lecture: Kp OK you want to let me pick a pen; you want to use the partial pressures OK

Student 2: No sir Kc the one for concentration.

Lecture: OK OK let's just stick to equilibrium OK

Student 2: Equals to concentration

Lecture: Okay of what?

Student 2: Of hydrogen gas to the power of 4, then divide by the concentration of water to the power of 4

Lecture: That’s correct and what is the unit?

Student 2: They will cancel each other since they are both to the power of 4

Lecture: Yes, it is unitless. Can you work out this one, then we would revise I think that would be the end, number two I did number 3 can you do number 2 OK how do we go about it? Who wants to pick it up?

Student 2: I think you have to start by calculating the change of B

Lecture: Change of B are you using the rice?

Student 2: Yes Sir

Lecture: alright I have a A, B, C what is the ratio?

Student 2: The ratio is 1:2:3

Lecture: OK and the initial amounts?

Student: Initial of A is 9.22, of B is 10.11 of C is 27.83

Lecture: 83 okay and then change?

Student 2: Should I give you the values of change or we start with what we are given?

Lecture: Start with what we are given, step by step

Student 2: Okay we given number of B at equilibrium its 18.32

Lecture: Okay 18.33

Student 2: Its 32 Sir

Lecture: 32 okay alright

Student 2: Then we calculate the change and I think its 8.21

Lecture: 8.21 right?

Student 2: We use that to calculate the change of A, uhm using the ratios and so its going to be 4, 105

Lecture: 105 okay?

Student 2: Then we calculate the change of C so its going to be 12, 315

Lecture: 12, 315 okay?

Student 2: Then we we calculate equilibrium moles of A

Lecture: Okay what is A?

Student 2: It is 5, 115

Lecture: And then of B

Student 2: Of B we have sir which is 18, 32

Lecture: 18, 32 and then of C?

Student 2: Of C is 40, 145

Lecture: Its what?

Student 2: Am not sure, its 40,145

Lecture: Right here you've been what, if you look at it now, we have been 10 it has increased. Here it has also, what has happened here?

Student 2: It has decreased

Lecture: No, no has it decreased? Why should it decrease?

Student 2: Isnt a reactant A

Lecture: Yeah these are reactants,

Student 2: Oh I made a mistake

Lecture: if this one will tell you if its increasing or not so here it is increasing which means this is increasing so you were supposed to add these. Then we get 13, something, what is the answer?

Student 2: 13.325

Lecture: 13. 325 okay right this is correct and here the reaction is lying to the left so it is decomposing, it is 3C decomposing so we subtract here.

Student 2: Okay so its 15, 515

Lecture: 15, 515 right that is at equilibrium so we need our equilibrium equation which will be C to the power of 3, concentration to the power of 1, concentration B to the power of 2. And uh this will be 15, 51 to the power of 3 divide

Student 2: by 13, 35 oh 3….

Lecture: 13, 325 to the power of 1, 18?

Student 2: 18, 32

Lecture: This is squared okay what will be the answer?

Student 2: 0,835

Lecture: 0, 835 what are the units?

Student 2: Mmmh I didn’t check…. Ah sir its unitless

Lecture: Let’s check it out it 3, 1 3 yes so 3-3 so it is zero yes, it is unitless, OK as I said we don't have much time to really talk about KSP and KP uh those dissociation constants. I think you'll be ready to write the test on the 5th as well as your examinations. OK and about the at the tutorial I think I've changed the tutorial for marks is due today midnight and the, am meeting today at 2:30 with the tutors who are going to do the moderation some have done it, some I do not actually met them to tell them how to moderate so we're meeting today so by the course of the week until Monday give me until monday check if nothing has happened email me please don't put it on the chats I'm not always on the, I will try to go through the chats but sometimes I miss some things but if it is an email I cannot miss that one I can take long but I cannot miss so if you have a query thank you to those who put the email and I've seen it and I've reply to it uh there are always people who want attention and they use the chat it's up to you but the email will be most appropriate and it is a trace which is acceptable by the university if you want to take it up you can draw it up without a problem so let's use email mostly to enquire to raise our issues and we will always try to meet you halfway any questions which we need to address? OK if there are no questions thank you so much and uh next week and infact from today on, after today you will be with Professor Bradley and you will be doing chemical and it what is it chemical energetics no no no it's not what is it electrostatics I think, I mean not electrostatics which am talking about it is electrochemistry something like that OK thank you have a wonderful day.